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SCIENCE AND CULTURE NEXUS

A Research Report

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Glen Aikenhead
Curriculum Studies
28 Campus Drive
Saskatoon, SK, S7N OX1
Canada

aikenhead@sask.usask.ca

Bente Huntley
SUNTEP Prince Albert
48 - 12th Street East
Prince Albert, SK, S6V 1B2
Canada

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EXECUTIVE SUMMARY

The goal of conventional science teaching has been to transmit to students the knowledge, skills, and values of the scientific community. This content conveys a Western worldview due to the fact that science is a subculture of Western culture. Thus, students with a much different worldview face a cross-cultural experience whenever they study Western science. How can these students master and critique a Western scientific way of knowing without losing something valuable from their own cultural way of knowing?

To First Nations science educator Madeleine MacIvor (1995), the answer is clear: "The need for the development of scientific and technical skills among our people is pressing. ... Reasserting authority in areas of economic development and health care requires community expertise in science and technology" (p. 74). "Conventional science must be presented as a way, not *the* way, of contemplating the universe" (p. 88). In other words, there is a need for First Nations and Métis students to learn Western science, but without necessarily being assimilated into Western culture.

To accomplish Madeleine MacIvor's goal, teachers need to develop in students the facility to cross cultural borders from their everyday world of family and tribe, into the subculture of school science. Many students do not cross this border smoothly because of cultural conflicts. They need a teacher who is a "culture broker". A culture-broker science teacher will help students move back and forth between an Aboriginal culture and the culture of Western science (conventional school science), and will help students deal with cultural conflicts that might arise.

If science teachers are not aware of the cultural aspects of Western science, and are not aware of the differences between scientific and Aboriginal cultures, then they will not make good culture brokers for Aboriginal students, and the science curriculum will be less accessible to these students. As a result, fewer Aboriginal students will succeed in science.

We would like to help teachers become better culture brokers, but first we needed to find out what teachers understood already. Our research project investigated science teachers' current awareness of the cultural aspects of Western science, and the connection between an Aboriginal student's home culture and the culture of science taught in their classroom. This connection, or "nexus", between a community's culture and the culture of Western science is captured by the phrase

"science and culture nexus" (SCN).

We developed some instruments that systematically gathered quantitative, qualitative data, and interview data from science teachers across northern Saskatchewan (from Yorkton to La Loche) who instructed First Nations or Métis students in grades 7 to 12. The views of Aboriginal science teachers were of special interest. Twenty-five teachers responded to a 69 item quantitative questionnaire, seven teachers responded to a 10 item qualitative questionnaire, and based on a preliminary analysis of these responses, a semi-structured interview was conducted with ten teachers. A total of 42 teachers participated.

We adopted a cultural view towards science education — teaching is cultural transmission while learning is culture acquisition. Because science tends to be a Western cultural icon of prestige, power, and progress, its subculture tends to permeate the culture of those who engage it, with cultural assimilation being one possible consequence. However, many students avoid cultural assimilation by playing "games" that allow students to pass their science course without really understanding the content. The rules of the game are known as "Fatima's rules" (as one teacher said, "students go with the information and memorize as much as they can without actually doing any new learning").

Alternatives to assimilation and Fatima's rules must be investigated. What actually happens when students move from their everyday culture into the culture of school science? The move is called "cultural border crossing". For the vast majority of students whose home worldview differs from the worldview of school science, cultural border crossing is *not* smooth. (Differences between First Nations cultures and Western science are itemized in the report.)

How easily do students move from their home culture into the culture of school science (ease of border crossing)? Anthropological research has identified four categories of ease, each related to differences between a student's culture and the culture school science: (1) congruent cultures support *smooth* transitions, (2) different cultures require transitions to be *managed*, (3) diverse cultures lead to *hazardous* transitions, and (4) highly discordant cultures cause students to resist transitions which therefore become virtually *impossible*. The ease with which Aboriginal students cross cultural borders into school science could likely determine a student's capability to learn Western science for practical purposes, and thus achieve goals defined by First Nations and Métis

educators, such as Madeleine MacIvor.

The *cognitive* experience of border crossing is captured by the idea called "collateral learning" — learning in the context of potentially conflicting knowledge (for example, Aboriginal or a student's personal knowledge versus Western science). Collateral learning was proposed by Olugbemiro Jegede (1995) who used a rainbow as an illustration. In the culture of Western science, students learn that the refraction of light rays by droplets of water causes rainbows; while in some African cultures, a rainbow signifies a python crossing a river or the death of an important chief. Thus for African students, learning about rainbows in science means constructing a potentially conflicting idea in their long-term memory. How do people resolve this conflict? The report discusses four types of collateral learning observed in students.

In summary, most students cross a cultural border when they enter a science classroom, some students less smoothly than others. A science teacher's role as culture broker will facilitate smoother border crossings into school science for Aboriginal students. Fatima's rules and collateral learning help explain how students react if their own worldviews differ from the worldview of Western science. These ideas guided our analysis of the study's empirical findings and helped us better understand teachers' beliefs science and culture and their nexus.

Results

Based on feedback from participants, our quantitative questionnaire has been revised. A shortened version of a Saskatchewan SCN instrument is now available for future use. It might help to identify groups of teachers who share similar views on the connection between their students' culture and the science taught at school.

The interview data produced our most credible results. The diverse and sometimes incompatible views expressed by the teachers gave considerable clarity to a wide range of ideas found in the quantitative and qualitative data. The interview data were organized around nine general questions: What is culture? What is science? What is the status and use of Aboriginal knowledge in science and science classrooms? Does the possession of Aboriginal knowledge inhibit students from learning science? If Aboriginal students do master science, do they loose something valuable from their own culture? Is there a connection between Western science and Euro-American

culture? To what extent is science a foreign culture to Aboriginal students? Why do Aboriginal students tend to avoid higher level science courses and science related careers? and In the context of teaching science to Aboriginal students, what is a science teachers primary responsibility?

The beliefs of the teachers seemed, on the surface, to be completely at odds with the views of the First Nations educators whose ideas were summarized above. Most teachers were articulate and persuasive in denying (or marginalizing) any cultural conflict between First Nations and scientific ways of knowing, until they were confronted with the fact that so few Aboriginal students entered science related fields, even among those who did go on to post-secondary education. The teachers' explanations for this fact spoke realistically to a variety of student inadequacies, for example, inadequacies in their self-confidence, language and math skills, academic orientation, and strength of family culture and support. But not one teacher broke through this wall of excuses, to see a more fundamental issue of cultural conflict for many Aboriginal students in school science. At the present time, therefore, our participants would probably not strongly embrace the need to become culture brokers to help Aboriginal students negotiate cultural borders between their family life culture and school science culture. Instead, teachers' efforts are currently directed towards adding a measure of Aboriginal content to conventional science instruction, towards participating in school-wide programs that teach Aboriginal knowledge, or towards engaging students in science activities that make connections to students' everyday worlds. However encouraging these approaches are, they tend to force students to navigate transitions between home and school science on their own.

What is the nature of First Nations and Métis students' educational experience in the K-12 public system? In addition to unconsciously abandoning students to negotiate cultural borders into science classrooms mostly on their own (specific efforts by a few teachers not withstanding), the results of our research suggest that while most teachers acknowledged the validity of Aboriginal knowledge, few stated that they were able to support Aboriginal students sufficiently by incorporating that content into their science classes. All teachers interviewed felt badly at the lack of resources that could help them support Aboriginal students adequately. This lack of resources was cited by most of the participants as the main reason that only a token amount of Aboriginal knowledge was introduced into their science programs.

The teachers in our study were unanimous in rejecting the idea that their science classrooms purposefully assimilated Aboriginal students into a Western worldview, though the teachers may have unintentionally worked towards assimilating some students into a Western way of thinking by not intentionally guarding against their assimilation.

In summary, teachers who want Aboriginal students to succeed in science must not be undermined by (1) a lack of instructional resources, (2) an absence of cross-cultural approaches to instruction, and (3) a pervasive school culture that inadvertently promotes Fatima's rules. Students whose families support a First Nations and Métis culture will prosper from a science curriculum framed by an Aboriginal worldview, while students who are disconnected from their cultural roots may not find such a curriculum to be relevant. It seems that many Saskatchewan classrooms have both types of students. This latter group challenges science educators to engage in community efforts to re-establish traditional values and knowledge so students will feel more connected to nature and to their First Nations and Métis cultures. Traditional values and knowledge may likely be controversial, however, in communities where opposition to First Nations spirituality is strong.

Conclusions

Our results show that when the teachers themselves experienced conflict between science and First Nations knowledge, they had diverse ways of dealing with it. Their diverse ways are described by different types of collateral learning. We should anticipate a match or mismatch between students and teachers in terms of the type of collateral learning they are comfortable with. If teachers are aware of their own preferred type of collateral learning, and are aware of the alternative types preferred by some of their students, then teachers can improve their instruction. This awareness improves the culture-broker role of science teachers.

Why do Aboriginal students avoid science in high school and university? About a half of our participants initially said they had no idea. They could not confidently make sense of the problem, let alone resolve it. Teachers need to develop a resolution so they can effectively encourage students to continue in science and mathematics. One promising resolution is to provide students with culturally responsive curricula, instruction, and assessment that make students feel more comfortable border crossing between their own culture and the culture of school science.

The interview data were replete with constraints that compromised successful science instruction. These constraints will not be diminished by adopting a cultural perspective on student learning (border crossing into the culture of school science with varying degrees of ease), but such a perspective could give us creatively new ways to circumvent some of those constraints.

Recommendations

Instances of culturally sensitive curriculum, instruction, and assessment were evident intermittently and on a small scale in our research data. Thus, the recommendations below speak to expanding the frequency of those examples so they become the conventional practice, rather than the celebrated exception.

1. Schools should validate and teach First Nations knowledge to a significant degree.
2. Knowledge of nature learned in school science should combine both Aboriginal and Western science knowledge. Our participants spoke of making connections between school science and the students' everyday lives. Students' Aboriginal culture/language/knowledge must be seen by students as an asset to learning Western science, not as a liability. A First Nations worldview should frame a science curriculum, within which appropriate Western science knowledge, skills, and values are studied in a cross-cultural way.
3. A group of teachers who are already fulfilling some of the roles of a culture broker should be identified and then organized into a network with other educators. This network would collaboratively carry out research and development (R&D) individually in classrooms and together as a group. Their mandate is defined in the report.
4. Saskatchewan Education, in conjunction with other agencies and organizations, should fund the network of educators, and should plan to expand the network once the initial R&D is completed.
5. Children in elementary schools (grades 1-6) should experience enough hands-on materials to develop routines of proper behavior around materials in classrooms. They should also learn that their hands-on experiences with materials and with nature are genuine instances of being a scientist themselves.

PURPOSE OF THE RESEARCH PROJECT

The goal of conventional science teaching has been to transmit the canonical content of science to students (the knowledge, skills, and values of the scientific community). This content, however, is imbued with a Western epistemology and worldview because of the way science has historically evolved within Western European culture (Ermine, 1995). In short, science is a subculture of Western culture (Pickering, 1992). Thus, students with a much different epistemology and worldview tend to be faced with a cross-cultural experience whenever they study Western science (Jegede, 1995; MacIvor, 1995; Ogawa, 1995).

A dilemma is faced by educators of First Nations and Métis students: How can students master and critique a Western scientific way of knowing without, in the process, sacrificing their own cultural ways of knowing? The response of First Nations science educator Madeleine MacIvor (1995) is clear: "The need for the development of scientific and technical skills among our people is pressing. ... [R]easserting authority in areas of economic development and health care requires community expertise in science and technology" (p. 74). "Conventional science must be presented as a way, not *the* way, of contemplating the universe" (p. 88). In other words, there is a need for First Nations and Métis students to learn Western science but without being assimilated by science's Western culture. Cultural assimilation must be assiduously avoided (Battiste, 1986).

To accomplish Madeleine MacIvor's goal for Aboriginal students, teachers need to develop in students the facility to cross cultural borders from their everyday worlds of family and tribe, into the subculture of school science (Aikenhead, 1997). Some students already cross this border smoothly, but many do not (Costa, 1995). Those who do not move smoothly into the subculture of science find border crossing hazardous, usually because of conflict between epistemologies or worldviews (Cobern and Aikenhead, 1997).

A teacher's role in resolving cultural conflicts that arise in cross-cultural border crossings was described by Stairs (1995) in terms of the teacher serving as a "culture broker". A culture-broker science teacher will help Aboriginal students move smoothly back and forth between an Aboriginal culture and the subculture of Western science (conventional school science), and will help students deal with cultural conflicts they might experience. A teacher who understands the

cultural nature of science and its cultural differences with Aboriginal cultures, will likely have a positive influence on students' success in school science (Aikenhead, 1997; Phelan et al., 1991; Stairs, 1995). Before a science teacher can assume the role of culture broker, however, he or she must recognize Western science as a cultural phenomenon and not just a body of canonical knowledge. This recognition will have a direct effect on his or her role as culture broker for First Nations and Métis students.

Research in the United States shows that most science teachers are not aware of the cultural aspects of Western science, and are not aware of differences in the epistemologies and worldviews between scientific and Aboriginal knowledge systems (Allen, 1995; Gallagher, 1991; Nelson-Barber and Estrin, 1995). Such teachers will not make good culture brokers for Aboriginal students, and consequently in Saskatchewan, the science curriculum will be less accessible to these students. As a result, fewer Aboriginal students will meet with success in K-12 science compared to their counterparts who have had a Western cultural upbringing (Aikenhead, 1997). In-service programs are needed to help teachers become good culture brokers to improve the quality of students' science education while avoiding the cultural assimilation into Western ways of thinking (Leavitt, 1995; Stairs, 1995).

Research Problem

Before a rational in-service program can be developed for science teachers (both Aboriginal and non-Aboriginal teachers) who instruct First Nations and Métis students, research is needed *to document Saskatchewan teachers' current understandings of the connection between a student's home culture and the culture of Western science taught in the classroom.* This connection, or nexus, between a community's culture and the culture of Western science is captured by the phrase "science and culture nexus" (SCN).

Research Objectives

The Science and Culture Nexus (SCN) research project is a *preliminary* study which, upon completion, will open a new avenue of R&D in Saskatchewan (future funding): classroom R&D, in collaboration with teachers and the First Nations and Métis communities, to produce teaching

strategies and materials to facilitate a teacher's role as culture broker in science classrooms. These teaching strategies and materials will be the practical content in in-service and pre-service programs. This R&D will require a research network of educators focused on improving First Nations and Métis students' success in K-12 science by making it more accessible to them.

Before this new avenue of R&D can be realized, however, three principal objectives must be achieved. These are described here.

A research instrument needs to be developed to document science teachers' understandings of the science and culture nexus. This need led to our first principal objective:

> *Objective 1*: *To develop a research instrument which systematically gathers both qualitative and quantitative data that convey science teachers' recognition and understanding of the connection between First Nations culture and the culture of Western science.*

The participation of First Nations and Métis educators in designing and developing this instrument ensured that our SCN instrument was sensitive and valid for Saskatchewan schools.

The quantitative and qualitative data obtained from this SCN instrument, plus data from follow-up interviews with science teachers across northern Saskatchewan who instruct First Nations or Métis students, led to a second principal objective:

> *Objective 2*: *To convey the various views on the science and culture nexus held by science teachers with various backgrounds who currently teach First Nations and Métis students in grades 7 to 12 in Saskatchewan.*

The data will reflect a variety of current views towards teaching science; views that lie between one extreme -- the assimilation of students into a Western epistemology/worldview -- and the other extreme -- a cross-cultural experience for students. The assimilation of students into a Western worldview can have a very negative impact on Aboriginal students (as argued in the "Literature Review" section of this report). Therefore, a teacher's view of assimilation has immediate consequences to the quality of instruction experienced by Aboriginal students. This circumstance addresses the Saskatchewan Department of Education's question: "What is the nature of Indian and Métis students' educational experience in the K-12 public system?" The information acquired from Objective 2 will strengthen our understanding of current science teaching and could lead to future improvements in curriculum and instruction for First Nations and Métis students, described above

as a future avenue of R&D in Saskatchewan. Of special importance will be the views of Aboriginal science teachers.

Our SCN research project focused on grades 7 to 12 because science is usually scheduled as a separate school subject at this level (rather than integrated into a holistic curriculum) and the age of the students suggests an intellectual maturity for which an explicit cross-cultural experience with science could be a reasonable aim of a science teacher (Ogawa, 1995).

During this preliminary SCN study, the researchers will be in contact with a number of people in the First Nations and Métis communities as well as with non-Aboriginal science teachers. Thus, a third principal objective was established:

> *Objective 3*: *To identify a potential network of Saskatchewan science teachers and community leaders interested in future collaborative R&D for two purposes (future funding): (1) to design and run pre-service and in-service programs for science teachers to help teachers become better culture brokers for First Nations and Métis students, and (2) to develop culturally sensitive science curricula and methods of instruction.*

With improvements to science curriculum and instruction, students will tend to enrol in more science courses and hence improve the number of First Nations and Métis students (1) opting for careers related to science and engineering without being assimilated into a Western worldview, and (2) being able to critique personal, community, national, or global issues related to science and technology (Aikenhead, 1997; MacIvor, 1995; Nelson-Barber and Estrin, 1995; Snively and MacKinnon, 1995).

LITERATURE REVIEW [1]

A research project investigating teachers' beliefs about the connection between science and culture requires us to adopt a cultural view towards science education. This section of the report reviews the relevant literature in educational anthropology and culture studies in science education. We will draw upon this literature to analyse our research findings.

Cultures and Subcultures

A cultural perspective on science education views teaching as cultural transmission and views learning as culture acquisition (Contreras and Lee, 1990; Spindler, 1987; Wolcott, 1991), where culture means "an ordered system of meaning and symbols, in terms of which social interaction takes place" (Geertz, 1973, p. 5). We talk about, for example, a Western culture, and Aboriginals speak of their First Nations cultures or their Métis cultures, because members of each group share, in general, a system of meaning and symbols for the purpose of social interaction. Geertz's definition is given more specificity by anthropologists Phelan, Davidson, and Cao (1991) who conceptualize culture as the norms, values, beliefs, expectations, and conventional actions of a group.

Other categories describing culture have been used by First Nations educators; for instance: material, social, cognitive, and linguistic aspects of culture (Leavitt, 1995); and ecological, social, and cognitive aspects of culture (Stairs, 1995). These categories relate to other views on culture found in science education, views such as: Maddock's (1981, p. 20) "beliefs, attitudes, technologies, languages, leadership and authority structures;" Tharp's (1989) social organization, sociolinguistics, cognition, and motivation; or Ogawa's (1986) views of humans, views of nature, and ways of thinking. In different science education studies different aspects of culture have been used to highlight particular interests in cross-cultural or multicultural education (reviewed in Aikenhead, 1996; Cobern and Aikenhead, 1997). Phelan et al.'s (1991) definition of culture (above) is

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[1]This review draws heavily from a recently published article (Aikenhead, 1997) and upon a manuscript in progress (Aikenhead and Jegede).

advantageous because it has relatively few categories and they can be interpreted broadly to encompass anthropological aspects of culture as well as the educational attributes often associated with science instruction: knowledge, skills, and values. Canonical scientific knowledge will be subsumed under "beliefs" in Phelan et al.'s definition.

Within First Nations and Métis cultures, subgroups exist that are commonly identified by nation, tribe, language, location, religion, gender, occupation, etc. Within Western cultures, subgroups are often defined by race, language, ethnicity, gender, social class, occupation, etc. A person can belong to several subgroups at the same time; for example, a female Cree middle-class research scientist or a Euro-Canadian male working-class technician. Large numbers and many combinations of subgroups exist due to the associations that naturally form among people in society. In the context of science education, Furnham (1992) identified several powerful subgroups that influence students' understanding about science: the family, peers, the school, and the mass media, as well as groups associated with various physical, social, and economic environments. Each identifiable subgroup is composed of people who generally embrace, or who in various different ways conform to, a defining set of norms, values, beliefs, expectations, and conventional actions. In short, each subgroup shares a culture, which we designate as "subculture" to convey an identity with a subgroup. Although a great deal of diversity exists within each subculture (due to a variety of factors), we can talk about, for example, the subculture of northern Saskatchewan Cree, the subculture of females, the subculture of our peers, the subculture of a particular science classroom, and the subculture of science.

The Subculture of Science

Science itself is a subculture of Western or Euro-American culture (Dart, 1972; Jegede, 1995; Maddock, 1981; Pickering, 1992; Ogawa, 1986; Pomeroy, 1994), and so "Western science" can also be called "*subculture science*." Scientists share a well defined system of norms, values, beliefs, expectations, and conventional actions -- the culture of Western science or "*the subculture of science*." These norms, values, etc. vary with individual scientists and situations (Aikenhead, 1985; Cobern, 1991, ch. 5; Kuhn, 1970; Gauld, 1982; Ziman, 1984) and have been investigated by scholars in a field called "social studies of science" (for example, Fourez, 1988; Kelly, Carlsen, and

Cunningham, 1993; Pickering, 1992; Rose, 1994; Snow, 1987; Stanley and Brickhouse, 1994). Their descriptions of the subculture of science often include the following attributes: mechanistic, materialistic, reductionist, empirical, rational, decontextualized, mathematically idealized, communal, ideological, masculine, elitist, competitive, exploitive, impersonal and violent. This list does not define subculture science but identifies some of its aspects described by the social studies of science literature.

Because science tends to be a Western cultural icon of prestige, power, and progress, its subculture permeates the culture of those who engage it (Baker and Taylor, 1995; Dart, 1972; Hodson, 1993; Jegede and Okebukola, 1990, 1991; MacIvor, 1995; Ogawa, 1995; Pomeroy, 1994; Swift, 1992). This acculturation can threaten indigenous cultures, thereby causing Western science to be seen as a hegemonic icon of cultural imperialism (Battiste, 1986; Ermine, 1995; Maddock, 1981; Simonelli, 1994). In the case of First Nations peoples, the threat is real. To understand their position it is necessary to appreciate some cultural aspects to their view of nature, a topic to which we now turn.

First Nations Knowledge of Nature

Aboriginal knowledge about the natural world contrasts with Western scientific knowledge in a number of ways. Aboriginal and scientific knowledge differ in their social goals: survival of a people *versus* the luxury of gaining knowledge for the sake of knowledge and for power over nature and other people (Peat, 1994). They differ in intellectual goals: to co-exist with mystery in nature by celebrating mystery *versus* to eradicate mystery by explaining it away (Ermine, 1995). They differ in their association with human action: intimately and subjectively interrelated *versus* formally and objectively decontextualized (Pomeroy, 1992). They differ in other ways as well: holistic First Nations perspectives with their gentle, accommodating, intuitive, and spiritual wisdom, *versus* reductionist Western science with its aggressive, manipulative, mechanistic, and analytical explanations (Allen, 1995; Ermine, 1995; Johnson, 1992; Knudtson and Suzuki, 1992; Peat, 1994; Pomeroy, 1992). "The Western world has capitulated to a dogmatic fixation on power and control at the expense of authentic insights into the nature and origin of knowledge as truth" (Ermine, 1995, p. 102). They even differ in their basic concepts of time: circular for Aboriginals, rectilinear for

scientists.

Aboriginal and scientific knowledge differ in epistemology. Pomeroy (1992) summarizes the difference succinctly:

> Both seek knowledge, the Westerner as revealed by the power of reason applied to natural observations, the Native as revealed by the power of nature through observation of consistent and richly interweaving patterns and by attending to nature's voices. (p. 263)

Ermine (1995) contrasts the exploration of the inner world of all existence by his people with a scientist exploring only the outer world of physical existence. He concludes:

> Those who seek to understand the reality of existence and harmony with the environment by turning inward have a different, incorporeal knowledge paradigm that might be termed Aboriginal epistemology (p. 103).

Battiste (1986) explicates an Aboriginal epistemology further by giving detail to what Pomeroy called "nature's voices":

> A fundamental element in tribal epistemology (lies) in two traditional knowledge sources:
>
> 1. from the immediate world of personal and tribal experiences, that is, one's perceptions, thoughts, and memories which include one's shared experiences with others; and
> 2. from the spiritual world evidenced through dreams, visions, and signs which (are) often interpreted with the aid of medicine men or elders. (p. 24)

On the one hand, subculture science is guided by the fact that the physical universe is knowable through rational empirical means, albeit Western rationality and culture-laden observations (Ogawa, 1995); while on the other hand, Aboriginal knowledge of nature celebrates the fact that the physical universe is mysterious but can be survived if one uses rational empirical means, albeit Aboriginal rationality and culture-laden observations (Pomeroy, 1992). For example, when encountering the spectacular northern lights, scientists would ask, "How do they work?' while the Waswanipi Cree ask, "Who did this?" and "Why?" (Knudtson and Suzuki, 1992, p. 57). Aboriginal knowledge is not static, but evolves dynamically with new observations, new insights, and new spiritual messages (Hampton, 1995; Kawagley, 1995; More, 1987).

The norms, values, beliefs, expectations, and conventional actions of First Nations peoples contrast dramatically with the subculture of science. In an earlier section, Western science was

characterized as being essentially mechanistic, materialistic, etc. By comparison, Aboriginal knowledge of nature tends to be thematic, survival-oriented, holistic, empirical, rational, contextualized, specific, communal, ideological, spiritual, inclusive, cooperative, coexistent, personal, and peaceful. Based on these two lists, Western science and Aboriginal knowledge share some common features (empirical, rational, communal, and ideological). Consequently, it is not surprising that efforts are underway to combine the two knowledge systems into one field called "traditional ecological knowledge" (Corsiglia and Snively, 1995; Johnson, 1992). While a *romanticized* version of a First Nations peaceful coexistence with the environment should be avoided, Knudtson and Suzuki (1992) document the extent to which environmental responsibility *is* globally endemic to First Nations cultures, a quality that led Simonelli (1994) to define "sustainable Western science" in terms of First Nations cultures. Simonelli (1994) quoted a Lakota ceremonalist's view of science and technology: "This is not a scientific or technologic world. The world is first a world of spirituality. We must all come back to that spirituality. Then, after we have understood the role of spirituality in the world, maybe we can see what science and technology have to say" (p. 11). Deloria (1992b), also of the Lakota nation, challenged the objective validity claimed by Western science when he spoke about improving the subculture of science by getting science to adopt a First Nations sense of contextualized purpose.

> The next generation of American Indians could radically transform scientific knowledge by grounding themselves in traditional knowledge about the world and demonstrating how everything is connected to everything else. Advocacy of this idea would involve showing how personality and a sense of purpose must become part of the knowledge which science confronts and understands. The present posture of most Western scientists is to deny any sense of purpose and direction to the world around us, believing that to do so would be to introduce mysticism and superstition. Yet *what could be more superstitious* than to believe that the world in which we live and where we have our most intimate personal experiences is not really trustworthy and that another mathematical world exists that represents a true reality? (p. 40, italics added)

Our brief characterization of Aboriginal knowledge of nature hints at the intellectual challenges faced by many First Nations students who attempt to cross the cultural borders between

their everyday world and the world of science. These intellectual challenges are exacerbated by a critical dilemma posed by the subculture of school science.

The Subculture of School Science

Closely aligned with Western science is school science, whose main goal has been cultural transmission of both the subculture of science (Cobern, 1991, ch. 5; Layton et al., 1993; Maddock, 1981; Pomeroy, 1994) and the dominant culture of a country (Archibald, 1995; Krugly-Smolska, 1995; Stanley and Brickhouse, 1994). Thus, the subculture of school science is comprised of a dynamic integration of these two main cultural influences, plus many more influences from diverse stakeholders in science education (Apple, 1979; Fensham, 1992). In this report we shall focus on the influence of the cultural transmission of science, but it is important to keep in mind the many other crucial influences experienced by educators of First Nations and Métis students.

Transmitting a scientific subculture can either be supportive or disruptive to students. If the subculture of science generally harmonizes with a student's everyday culture, science instruction will tend to support the student's view of the world, and the result is *enculturation* (Contreras and Lee, 1990; Driver, Asoko, Leach, Mortimer and Scott, 1994; Hawkins and Pea, 1987). But if the subculture of science is generally at odds with a student's everyday world, as it can be with First Nations and Métis students (according to some authors reviewed above), then science instruction can disrupt the student's view of the world by forcing that student to abandon or marginalize his or her indigenous way of knowing and reconstruct in its place a new (scientific) way of knowing. The result is *assimilation* (Jegede, 1995; MacIvor, 1995) which in some circles has highly negative connotations as evidenced by such epitaphs as "cultural imperialism" (Battiste, 1986, p. 23), the "arrogance of ethnocentricity" (Maddock, 1981, p. 13), and "racist" (Hodson, 1993, p. 687). Assimilation has caused oppression throughout the world and has disempowered whole groups of people (Gallard, 1993; Hodson, 1993; Urevbu, 1987), including Canadian First Nations peoples (Barman et al., 1986; Ermine, 1995).

Although the cultural function of school science has traditionally been to enculturate or assimilate students into the subculture of science (a prime example is *Science for All Americans*, AAAS, 1989), many students persistently and ingeniously resist assimilation (Driver, 1989; Hills,

1989; West and Pines, 1985) by playing a type of school game that allows them to pass their science course without learning the content assumed by the teacher and community. The game can have explicit rules which Larson (1995) discovered as "Fatima's rules," named after an articulate student in a high school chemistry class. Latour (1987) anticipated the phenomenon when he noted one of the cultural expectations of school science: "Most schooling is based on the ability to answer questions unrelated to any context outside of the school room" (p. 197). Fatima's rules tell us how to do just that without understanding the subject matter meaningfully. For instance, one rule advises students not to read the textbook but to memorize the bold faced words and phrases. This cultural perspective on the conventional school science curriculum is summarized in Table 1.

Table 1 fits here. See Appendix 1.

Understandably most First Nations and Métis educators reject the conventional science curriculum (Archibald, 1995; MacIvor, 1995), but they face a dilemma: how does one nurture students' achievement toward formal educational credentials and economic and political independence, while at the same time develop the students' cultural identity as Aboriginals (Kawagley, 1995; Leavitt, 1995; Nelson-Barber and Estrin, 1995; Philips, 1972; Snively, 1995; Stairs, 1995)? In other words, to what extent, and how, can First Nations and Métis students learn non-Aboriginal school subjects such as Western science without being harmfully assimilated by its dominant Western culture?

Responses to the dilemma range between two extremes, each representing a different amount of risk of assimilation. At the low-risk extreme, educators dedicate themselves to preserving the culturally distinctive modes of communication, thought, and life styles of the students' Aboriginal culture. For instance, "Inquisitiveness about mystery and continued exploration of the inner space is a legacy we must promote in our own lives" (Ermine, 1995, p. 105). At the high-risk extreme, educators push talented students into a science career "pipeline," hoping that their success as a future role model will outweigh any personal loss to their self-identity as an Aboriginal (Massey, 1992).

The middle ground between these two extremes has been charted by Stairs (1995) in terms

of the *degrees* of incorporating Aboriginal culture into current school practice (a five-step hierarchical model beginning with instruction in students' indigenous language -- a "limited cultural inclusion" first step), and by Pomeroy (1994) in terms of nine distinct *research agendas* she abstracted from the science education literature: (1) science and engineering career support projects, (2) an indigenous social issues context for science content, (3) culturally sensitive instructional strategies, (4) historical non-Western role models, (5) demystifying stereotype images of science, (6) science communication for language minorities, (7) indigenous content for science to explain, (8) compare and bridge students' worldviews and the worldview of science, and (9) explore the content and the epistemology of both Western and Aboriginal knowledge of the physical world. Pomeroy (1994) pointed out:

> The nine agendas ... generally move from a more static multicultural view, which maintains the structure of the institutions of science and culture as they are, to a more dynamic inter, or cross-cultural view which requires deconstruction of the view of Western science as universal with a new construction of and, most important, access to alternative views and methods. (p. 68)

Agendas one to seven lead to the assimilation of students into Western science, while agendas eight and nine challenge us to conceive of alternatives to assimilation (and to Fatima's rules). Pomeroy drew upon Giroux's (1992) *Border Crossings* to suggest that teachers and students should together become "cultural border crossers" (Pomeroy, 1994, p. 50), a theme we elaborate in a later section.

MacIvor's (1995) response to the dilemma faced by First Nations educators belongs to Pomeroy's ninth agenda because MacIvor proposes an integration of Aboriginal and science education for the survival and well being of First Nations peoples: "The need for the development of scientific and technical skills among our people is pressing. ... [R]easserting authority in areas of economic development and health care requires community expertise in science and technology" (p. 74). This resolution to the dilemma holds promise.

According to MacIvor, school science should encourage students to learn science in a way that empowers them to make everyday choices about participating in either a First Nations cultural setting or the dominant Canadian cultural setting. Students would be capable of engaging in modes of communication, life styles, thought processes, and occupations of either culture (Hodson, 1992;

Philips, 1972). In other words, First Nations students should develop the facility to cross cultural borders from the everyday subcultures of their peers, family, and tribe, into the subcultures of school science, and science and technology. These border crossings may be essential for First Nations and Métis students.

Border Crossings

Two scenarios illustrate some of the difficulties that First Nations and Métis students can encounter when they move between cultures or subcultures. In each scenario a misunderstanding arises because at least one of the players does not recognize that a cultural border has been crossed.

1. Two Aboriginal students in Susan Chandler's 10th grade science class again did not follow her lab instructions. When she reviewed her instructions for these lab partners, her frustration peaked as she demanded, "Look me in the eye when I'm speaking to you!" Susan had failed to realize the deep respect the two students thought they were showing her by not making eye contact when she explained what they had done wrong.
2. University science student Coddy Mercredi disobeyed his faculty advisor by avoiding geology courses throughout his university career. Coddy did not want to spoil his aesthetic understanding of nature's beauty by polluting his mind with mechanistic explanations of the earth's landscapes. He understood science all too well and chose not to cross one of its borders. His advisor thought he was lazy and not worthy of a science scholarship.

These scenarios alert us to the potential obstacles that students face when they travel from the culture of their everyday world to the subculture of a science classroom and to the subculture of science itself. Coddy Mercredi, for instance, feared he would be assimilated by geology and therefore border crossing for him was problematic. For some students, however, such border crossings seem easy to negotiate.

Research in developing countries has identified problems experienced by students who have an indigenous "traditional" background and attempt to learn a subject matter grounded in Western culture (Akatugba and Wallace, 1996; Baker and Taylor, 1995; Dart, 1972; George and Glasgow, 1988; Jegede, 1995; Jegede and Okebukola, 1990, 1991; Knamiller, 1984; Pomeroy, 1994; Swift, 1992). Similar research with minority students in Western countries has also documented obstacles

for students (Allen, 1995; Atwater and Riley, 1993; Barba, 1993; Contreras and Lee, 1990; Krugly-Smolska, 1995; Lee, Fradd and Sutman, 1995; Rakow and Bermudez, 1993). Allen (1995), for instance, documented worldview differences between Kickapoo Native American children and their science instruction; differences that make cultural border crossings "perilous" for many students. (Interestingly, many Western students in Western science classes face similar problems; Aikenhead, 1996; Cobern and Aikenhead, 1997; Ogawa, 1995.) Pomeroy's (1994) review of cross-cultural studies (summarized above) addresses both non-Western and minority domains of research, and also overlaps with reviews of First Nations research in science education (MacIvor, 1995; Nelson-Barber and Estrin, 1995). One ubiquitous research finding from all of these reviews was summarized by Hennessy (1993, p. 9) when she concluded, "Crossing over from one domain of meaning to another is exceedingly hard."

Border crossings need not always be problematic, however. In our everyday lives we exhibit changes in behaviour as we move from one social setting to another; for instance, from our colleagues at work to our families at home. As we move from the one subculture to the other, we intuitively and subconsciously alter certain beliefs, expectations, and conventions; in other words, we effortlessly negotiate the cultural border between professional and family settings. Only a few researchers have studied individual differences in terms of moving in and out of Western science. Medvitz (1985) documented cases of Nigerian scientists who moved effortlessly between the subcultures of a scientific laboratory and their tribal village, even when they recognized the contradictions between the two. Similar results were found for some high school graduates in a rural Melanesian culture in the South Pacific (Waldrip and Taylor, 1994). One of Medvitz's (1985) participants reported:

> It (the ability to shift cognitive patterns) is very interesting to us and we talk about it among ourselves in the university. When we are in our offices and laboratories we behave very scientifically. When we go home we make sure that the water is boiled for our babies. But when we put on our robes and go home to the villages and visit our parents and elders, we think very differently. It's not that we are behaving in a way to please them. It's that we are *thinking* differently. (p. 14, emphasis in the original)

A multiple-world outlook does not necessarily discourage students from learning science. A First

Nations educator argued: "It's okay to be educated in two worlds in two ways. ... People think differently, that's okay -- differences don't have to get in the way of bringing things together" (Henderson, 1996, p. 23). A First Nations student (Judy), steeped in her Aboriginal culture and who majored in the sciences at university, expressed her ideas on a final examination at the University of Saskatchewan:

> I believe that once a person chooses to become a scientist, he/she enters a world in which there already exists a distinct culture; that of the subculture of Western science. Often a person chooses to enter the subculture of Western science because his/her own culture did not satisfactorily deal with the questions of the world around her/him and decided to become a scientist in order to find some kind of understanding with his/her world. Thus, in doing so, the person leaves behind his/her own culture and embraces the world according to the subculture of Western science.

Judy expressed a harmony in border crossing that consciously acknowledged multiple worlds. Her learning was sustained by being able to cross smoothly in and out of Western science.

On the other hand, Aikenhead and Binsfeld (1996) reported holistic outlooks expressed by First Nations and Métis high school students in grade 10 science when interviewed about science bringing them closer to, or further away from, their Aboriginal culture. Lakota spoke for many students when she said:

> Well, I don't think there really is any difference, between my culture and science. Because we still have a lot of things to learn in our culture, and there's still a lot of things in science we have to learn. ... Like I don't look at [answers in science] any different. Because I find something out in science, and then something in my culture is happening, it doesn't conflict. You know, there's no fuzz in between. I know which side is which. Like, you know, it doesn't conflict. (Lakota, Oct. 98-108)

Lakota would seem to have learned science through a holistic outlook towards her thinking. Her view is echoed in Crozier-Hogle and Wilson's (1996) *Surviving in Two Worlds: Contemporary Native American Voices*. Windham (1997) attributed the success of Native American students in an "atmospheric science" summer program to their appreciation of the complementarity of science and traditional knowledge (exemplified by Lakota's type of learning).

Visa versa, border crossing was experienced by a Western physicist when he moved into a First Nations worldview. Peat (1994, p. 42) described his experiences in terms of *thinking differently*: "we should all learn to talk and listen together without prejudgment, learn to suspend our prejudices, and allow our consciousness to flow along new lines".

One fundamental conclusion can be reached: *The capacity and motivation to participate in diverse subcultures are well known human phenomena.*

However, such capacities and motivations are not shared equally among all humans, as anthropologists Phelan et al. (1991) discovered when they investigated students' movement between the worlds of their families, peer groups, schools, and classrooms:

> Many adolescents are left to navigate transitions without direct assistance from persons in any of their contexts, most notably the school. Further, young people's success in managing these transitions varies widely (p. 224).

The significance of these results has direct implications for First Nations and Métis students:

> Yet students' competence in moving between settings has tremendous implications for the quality of their lives and their chances of using the education system as a stepping stone to further education, productive work experiences, and a meaningful adult life. (p. 224)

Phelan et al.'s data suggested that differences between students' worlds lead to four types of transitions: congruent worlds support *smooth* transitions, different worlds require transitions to be *managed*, diverse worlds lead to *hazardous* transitions, and highly discordant worlds cause students to resist transitions which therefore become virtually *impossible*.

Costa (1995) provides a link between Phelan et al.'s anthropological study of schools and the specific issues faced by science educators. Based on the words and actions of 43 high school science students enrolled in two Californian schools with diverse student populations, Costa concluded:

> Although there was great variety in students' descriptions of their worlds and the world of science, there were also distinctive patterns among the relationships between students' worlds of family and friends and their success in school and in science classrooms. (p. 316)

These patterns in the ease with which students move into the subculture of science were described in terms of familiar student characteristics, and then clustered into five categories (summarized here

in a context of cultural border crossing): (1) "Potential Scientists" cross borders into school science so *smoothly* and naturally that the borders appear invisible; (2) "Other Smart Kids" *manage* their border crossing so well that few express any sense of science being a foreign subculture; (3) "'I Don't Know' Students" confront *hazardous* border crossings but learn to cope and survive; (4) "Outsiders" tend to be alienated from school itself and so border crossing into school science is virtually *impossible*; and (5) "Inside Outsiders" find border crossing into the subculture of school to be almost *impossible* because of overt discrimination at the school level, even though the students possessed an intense curiosity about the natural world.

Costa's research provides a framework within which important issues in First Nations and Métis education can be identified and discussed. The ease with which Aboriginal students cross cultural borders into the subculture of science, for instance, can be described roughly by Costa's categories, and these categories have implications for curriculum development (Aikenhead, 1996). In addition, the ease of border crossing could likely determine a student's capability to raid Western science for practical ends and achieve goals defined by First Nations and Métis educators (Kawagley, 1990, 1995; MacIvor, 1995).

In this cross-cultural science education, students become cultural border crossers between Aboriginal cultures and the subculture of science. The metaphor "teacher as culture broker" was used by Stairs (1995) to analyse the teacher's role in resolving cultural conflicts that arise in cross-cultural education for First Nations and Métis students. A culture broker helps smooth the border crossings that many First Nations and Métis students experience when they enter a science classroom. A culture-broker teacher will "help students feel that the school program is a natural part of their lives and help them move more smoothly back and forth between one culture and the other" (Leavitt, 1995, p. 134). Students' intelligence and ingenuity ensures their resilience during hazardous border crossings into the subculture of science, as long as students feel respected, and provided that the science content enhances the goals of First Nations and Métis peoples (Kawagley, 1995). In cross-cultural science education, students are "tourists" in a foreign culture and depend on culture-broker teachers to be "tour guides" or "travel agents" who take (or send) students across cultural borders into Western science and direct the use of science and technology in the context of the students' everyday world (Aikenhead, 1996). Some students need a great deal of help, while

others need independence, when they cross into the subculture of science. Snively (1990) describes how a teacher became such a travel-agent culture broker for both Aboriginal and non-Aboriginal students in her classroom.

In summary, learning science can be conceptualized as culture acquisition that requires either (1) less-than-smooth cultural border crossings into the culture of science for most students (Other Smart Kids, "I Don't Know" Students, and Outsiders); or (2) an apprentice-like rite of passage (Costa, 1993; Hawkins and Pea, 1987) into the culture of science for a small minority of students (Potential Scientists) for whom border crossings are so smooth that borders seem non-existent.

This cultural perspective will be clarified further by exploring some cognitive mechanisms that can assist students avoid Fatima's rules and negotiate cultural border crossings into the world of science. The *cognitive* experience of border crossing is captured by the theory of collateral learning (Jegede, 1996), to which we turn next in our review of the literature.

Collateral Learning

Potential Scientists can be found in all cultures (Kawagley, 1990; Ogawa, 1995), not just in Western countries. In Western countries, however, the enculturation of Potential Scientists into Western science likely proceeds more harmoniously than for Potential Scientists in *non*-Western cultures who are more likely to confront cognitive conflict between the tenets of their indigenous culture and the tenets of Western science. Consequently, non-Western Potential Scientists will likely construct scientific concepts side by side, and with minimal interference and interaction, with their indigenous concepts (related to the same physical event). This conceptual construction is called *collateral learning* (Jegede, 1995, 1997). Concepts are constructed as cognitive schemata stored in long-term memory. A simple example of collateral learning is illustrated by a rainbow. In the culture of Western science, students learn that the refraction of light rays by droplets of water causes rainbows; while in some African cultures, a rainbow signifies a python crossing a river or the death of an important chief. Thus for African students, learning about rainbows in science means constructing a potentially conflicting schema in their long-term memory. Not only are the concepts different (refraction of light versus pythons crossing rivers), but the epistemology also differs ("causes" versus "signifies").

Domain of Application

The phenomenon to which collateral learning refers is universal and well known worldwide (Goodman, 1984; Hennessy, 1993; Hortin, 1971; Medvitz, 1985; Wiredu, 1980). In 1972, for example, Dart noted how easily Nepalese children and adults talked about earthquakes and other natural events using folk-oriented or school-oriented explanations. "Surprising is the fact that each group nearly always gave both of the types of answers and all members generally accepted both" (p.51). Solomon (1983, 1984, 1992) in the UK documented conceptual differences between students' life-world ideas about energy and the scientific concept of energy, and she explored how students moved with great difficulty between the two domains. On the other hand, Ogunniyi (1988) explained that an indigenous cosmology which conflicts with Western science thinking need not preclude an understanding of science. It is possible to hold simultaneously an indigenous and scientific view of the world. Hodson (1992, p. 16) extended this argument by suggesting that "the task of science teaching is to help all children acquire scientific knowledge, interests, skills, attitudes and ways of thinking without doing violence to their particular cultural beliefs and experiences." Ogawa (1995) from Japan delineated Hodson's "particular cultural beliefs and experiences" by proposing three types of "science": personal science (the result of personal beliefs and experiences with nature), indigenous science (the communal beliefs and experiences of a micro-culture or culture, knowledge which may or may not converge with one's personal science), and Western modern science. Ogawa argued that teaching Western modern science is enhanced when students become aware of the corresponding personal and indigenous sciences in the classroom ("multiscience teaching"). In other words, Ogawa acknowledged collateral learning and suggested that students become aware of their conflicting schemata. Waldrip and Taylor (1997) found that Melanesian high school students in a small South Pacific country were aware of conflicting schemata between school science and the indigenous ideas of their village life. These students coped with discrepancies by employing a process Waldrip and Taylor called the "compartmentalization" of school knowledge (a type of collateral learning). Because of students' compartmentalization of school science, Waldrip and Taylor "obtained disturbingly little evidence of the influence of the Western school view of science on young people's traditional world views" (p. in press). Students and elders alike felt that school knowledge was not useful to village life (except for reading and

writing). The researchers' negative view of compartmentalization (a type of collateral learning) is challenged by Lowe (1995). Based on his research in the Solomon Islands, he concluded "To compartmentalize the world into domains, each with an interpretive framework [Western science versus Solomon Island magic], is not a perversity but an effective survival technique" (p. 665).

The effectiveness of the technique (of compartmentalization) was warranted in Lugones' (1987) account of how she survived in the world of the White Anglo male by being a different person in different domains without losing her self-identity in any of the domains. Her movement between domains was facilitated by being able to negotiate cultural borders through flexibility, playfulness, and the feeling of ease. Lugones' effectiveness is mirrored in the Japanese experience of wearing a Western business suit but maintaining a bamboo heart.

An implication for science teaching is clear: Effective collateral learning in science classrooms will rely on successful cultural border crossings into school science. Collateral learning and border crossings are fundamentally interrelated.

Collateral learning was proposed to explain why many students, non-Western and Western, experienced culturally related cognitive dissonance in their science classes (Jegede, 1995). Although the theory's domain of application includes Western students, there are exceptions. Members of Costa's (1995) Outsiders and Potential Scientists would normally not engage in collateral learning, each group for different reasons (discussed below). If Western students are to learn science in any meaningful way, they too will most likely construct scientific concepts side by side and with minimal interference and interaction with their commonsense preconceptions (their indigenous knowledge). Constructing scientific concepts is a learning experience usually identified as a mode of constructivism, and has been the object of two decades of research in science education (Driver et al., 1994; Geelan, 1997; Solomon, 1984, 1994; Tyson et al., 1997). As described earlier in this report (and consistent with constructivist research), many students avoid constructing scientific concepts by playing Fatima's rules. Playing Fatima's rules is not generally considered to be an instance of collateral learning, because playing Fatima's rules usually does not result in forming schemata in long-term memory. Consequently, three groups of students do not generally engage in collateral learning: Potential Scientists in Western schools, Outsiders, and any student playing Fatima's rules. Collateral learning proposed in this report will apply mainly to all other students.

There will be exceptions, of course.

Types of Collateral Learning

Collateral learning generally involves two or more conflicting schemata held simultaneously in long-term memory. Jegede (1995, 1996, 1997) recognized variations in the degree to which the conflicting ideas interact with each other and the degree to which conflicts are resolved. Three types of collateral learning are briefly introduced here and then clarified by examples that show what role they play in learning science. Lastly, a fourth type of collateral learning is acknowledged. These four types of collateral learning are not separate categories but points along a spectrum depicting degrees of interaction/resolution.

At one extreme of collateral learning, the conflicting schemata do not interact at all. This is *parallel* collateral learning, the compartmentalization technique. Students will access one schema or the other depending upon the context. For example, students will use a scientific concept of energy only in school, never in their everyday world where commonsense concepts of energy prevail (Solomon, 1983, 1984). This segregation of school science content within the minds of students was called "cognitive apartheid" by Cobern (1996b).

At the opposite extreme of collateral learning, conflicting schemata consciously interact and the conflict is resolved in some manner. This is *secured* collateral learning. The person will have developed a satisfactory reason for holding on to both schemata even though the schemata may appear to conflict, or else the person will have achieved a convergence towards commonality by one schema reinforcing the other, resulting in a new conception in long-term memory. Various ways to resolve conflicts and to achieve secured collateral learning are described in the next section of this report.

Between these two extremes of parallel and secured collateral learning we find varying degrees and types of interaction between conflicting schemata, and we detect various forms of conflict resolution. In this context it will be convenient to designate a point in between the extremes called *dependent* collateral learning. (A fourth type of learning -- simultaneous collateral learning -- will be introduced later in a more logical context.) Dependent collateral learning occurs when a schema from one worldview or domain of knowledge challenges another schema from a different

worldview or domain of knowledge, to an extent that permits the student to modify an existing schema without radically restructuring the existing worldview or domain of knowledge. A characteristic of dependent collateral learning is that students are not usually conscious of the conflicting domains of knowledge and consequently, students are not aware that they move from one domain to another (unlike students who have achieved secured collateral learning).

For many students, learning science meaningfully often involves cognitive conflicts of some kind. Therefore, meaningful learning often results in parallel, dependent, or secured collateral learning. Each of the three types of collateral learning will be illustrated by re-analysing some recently published research studies in terms of collateral learning.

An example of *parallel* collateral learning is found in a British study. Solomon et al. (1994) investigated changes to students' preconceptions about scientists and scientific activities. Students studied stories from the history of science and discussed why scientists conducted the experiments they did, and what scientists expected to find. The researchers discovered that the preconceptions held by students (students' life-world images of the nature of science) were *augmented*, not replaced, by the history of science instruction. Parallel collateral learning had taken place. As a result of the instruction, two sets of images of the nature of science coexisted in the long-term memories of students. Each set was cued by context, as the interviewers discovered.

In an extension of their first study, Solomon et al. (1996) abstracted from their new interview data three different ways that conflicting knowledge interacted in the minds of their students. Each way corresponds to a different type of collateral learning:

1. Parallel collateral learning: "They might keep the two kinds of 'science' quite separate as if what they did in school was quite different from the activities of remote and knowledgeable scientists" (p. 497).
2. Dependent collateral learning: "They might produce an amalgam or well-stirred mixture of the two kinds of knowledge" (p. 496).
3. Secured collateral learning: "They might be able to reflect on the similarities between their own work in science and that of scientists. This, we thought, would only happen if the students were enabled to discuss the purposes of experiments and the status of theory in their own work" (p. 497).

Dependent collateral learning occurs when a student's preconception or indigenous belief is: (1) contrasted with a different conception encountered in the science classroom, (2) given a tentative status, and then either (3) altered by reconstructing the original schema under the influence of the newly encountered schema, or (4) rejected and replaced by a newly constructed schema. In other words, students modify or reject their original schemata because it makes sense to them to do so. As Cobern (1996b, p. 601) argued, this happens when scientific ideas "hold scope and force in student lives." Dependent collateral learning is similar to the Piagetian accommodation-assimilation model of information processing associated with Posner et al.'s (1982) model of conceptual change. A critical difference between the two lies in the degree of imposition of conceptual change on students (cultural assimilation). For example, Arseculeratne (1997) discussed a problem in Sri Lanka and other technologically underdeveloped countries where people do not incorporate modern scientific thinking into their culture, in spite of using modern technology and scientific techniques. He blamed society's traditional ideas and modes of thinking. His solution was avoid "imposing alien ideas on different modes of thinking" (as the Posner et al. model tends to do) "by modifying and elaborating seemingly naive traditional beliefs ... without arrogance and patronage but with sensitivity" (p. 267). Arseculeratne's solution is dependent collateral learning. From a perspective of cultural anthropology, dependent collateral learning is the cognitive explanation for *acculturation* -- the selected modification of currently held ideas and customs under the influence of another culture (Spindler, 1987). In the context of teaching Western science to First Nations (Native American) students in Canada, Aikenhead (1997) described "autonomous acculturation" as one way for First Nations peoples to appropriate knowledge from Western science to fulfill their own practical needs (such as economic development, environmental responsibility, and cultural survival). An illustration of dependent collateral learning (the cognitive equivalent to acculturation) is found in the case study of a Trinidadian woman, Mrs. S., who combined aspects of Western medicine with her indigenous folk medicine (George, 1995). Mrs. S. offered definitive advice on matters of health. Some advice came from Western thinking, the rest came from her wealth of indigenous knowledge. At no time was she ambiguous over what domain to use, nor did she contrast the two domains of knowledge. Different and conflicting belief systems can occupy what Rampal (1994, p. 137) called "complementary domains in the space of social cognition." The belief systems are interwoven and

interdependent, and there is not conscious awareness of the various beliefs systems.

Instances of *secured* collateral learning in the research literature tend to be goals for us to aim for in science education. Lowe (1995), in his Solomon Island study, argued for a sophisticated view of learning beyond the simple dichotomy of "science versus traditional knowledge." His proposed view would empower students for life in our modern world. He concluded:

> students of science are in fact able to retain much of their traditional world-view while still appreciating the new view that science offers. They see science as opening up new horizons without losing sight of the old ones, and *develop strategies to deal with apparently incompatible visions*. (pp. 665-666, italics added)

These strategies are discussed in the following section. In the USA, Tobin and his colleagues (1997) raised the issue of empowerment in the context of students settling conflicts between scientific claims and students' everyday notions of common sense. "Empowerment is associated with an awareness that a knowledge claim does not make sense, and with having the discursive resources [cultural capital] to resolve the conflict at an appropriate time" (p. 506). This position was also advanced by Allen (1995), MacIvor (1995), and Nelson-Barber and Estrin (1995) for First Nations (Native American) students; and by Atwater (1996), Lee (1997a), Krugly-Smolska (1996), and others for marginalized students in North America. Along similar lines, Cobern (1996b, p. 604) thought that students should develop "a new or modified understanding of the world based on new concepts and ideas but concepts and ideas interpreted in the light of culturally grounded meaning. One possible result is the development of complementary thinking which is exemplified by the discourse between science and Christian faith."

A fourth type of collateral learning should be introduced: *simultaneous* collateral learning. This fits in-between parallel and dependent collateral learning on the spectrum described above. A unique situation can occur in which learning a concept in one domain of knowledge or culture can facilitate the learning of a similar or related concept in another milieu. It does not happen often but when it does, it is usually co-incidental. For instance, suppose a Nigerian student is studying photosynthesis in school and comes across terms such as "chlorophyll," "denaturing," and "chloroplast." Initially he or she will likely have problems comprehending these concepts. But suppose that after encountering the concepts in school, he or she finds something that makes the

school science vivid while helping mother in the kitchen. In Nigeria, people often blanch (with boiling water) green vegetables before adding them to soup. During this preparation the vegetables are left for some minutes to soak in the boiling water, and the vegetables lose some of their green colouration (chlorophyll). When people drain the water, all they see is green colour. In that situation, a student might simultaneously learn more about the school concepts of chlorophyll, denaturing, and photosynthesis while learning to prepare soup with green vegetables at home. In these two settings (home and school), learning about a single or related concept is usually not planned (except by a teacher who is a good culture broker, a topic taken up later), but arises spontaneously and simultaneously. By reflecting on the two settings and their concomitant concepts (e.g. green blanched water and chlorophyll), a student will easily cross the cultural border between home and school science. The two sets of schemata established in long-term memory by simultaneous collateral learning may over time: (1) become further compartmentalized, leading to parallel collateral learning, or (2) interact and be resolved in some way, resulting in either dependent or secured collateral learning, depending on the manner in which the conflict is resolved.

Summary

Our review of the literature has introduced the reader to a cultural perspective on science education. This literature informed our Science and Culture Nexus project: by clarifying an anthropological view of culture, by contrasting First Nations knowledge of nature with the culture of science and school science, by recognizing that most students cross a cultural border when they enter a science classroom, by defining these cultural border crossings in terms of Costa's (1995) categories that depict how smoothly students cross borders, by recognizing a science teacher's role as culture broker in facilitating smooth border crossings into school science for Aboriginal students, by proposing a theory to explain how students cognitively react to conflicting ideas in their science classrooms. These ideas will help us analyze the empirical findings of our research project, and thus help us better understanding teachers' beliefs about the connection between science and culture. A summary of the relationships among border crossings, student categories, roles of teachers, and collateral learning is found in Table 2.

Table 2 fits here. See Appendix 1.

METHODS

The first two research objectives of the SCN project were to develop an SCN instrument and to convey current beliefs of some science teachers about the connection between science and culture. Three different research methods were employed. One followed the quantitative paradigm of educational research which produces quantitative data (responses to a questionnaire using a five-point Likert-type format -- responses along a five-point scale: strongly agree, agree, unsure, disagree, strongly disagree). The second method followed an interpretive paradigm of educational research which produced qualitative data (written responses to a questionnaire). The third method, teacher interviews, also belongs to the interpretive paradigm of research. Each method has an instrument associated with it. These instruments are described here, beginning with the quantitative instrument, along with a discussion of what research has discovered about these types of instruments.

Research Instruments

A draft version of an international Science and Culture Nexus (SCN) instrument had been developed by Drs. O. Jegede (Nigeria/Australia), G. Aikenhead (Canada), M. Ogunniyi (South Africa), and W. Cobern (United States), as part of an ongoing unfunded research project. This instrument served as a point of departure for composing a Saskatchewan version of the SCN instrument. Both the international and the Saskatchewan versions consisted of section A (biographical data) and section B (items for teachers to react to). Reactions to each item were communicated on a Likert-type scale. In addition, each item in section B required reactions from two different perspectives: (1) what teachers perceived to be the views of their colleagues (to determine their sense of isolation among their colleagues, if any), and (2) what teachers thought themselves. The items were organized around the following five topics: science, science and culture, science and indigenous knowledge, culture, and teaching and learning science. The original international version had 40 items while the Saskatchewan trial version had 67 items.

In addition to the *quantitative* form of the SCN instrument, a *qualitative* form was composed, where teachers wrote out their reasons for choosing the Likert-type responses they had picked. The qualitative instrument was composed of 10 items drawn from the quantitative instrument. The trial

versions of both the quantitative (67 items) and qualitative (10 items) SCN instruments were developed in collaboration with Aboriginal university scholars. Both the quantitative and qualitative instruments may be found in Appendix 2.

The quantitative data roughly tell us which items received general agreement, disagreement, or a diverse reaction, from teachers. However as Aikenhead et al. (1987), Lederman and O'Malley (1990), and Mellado (1997) have shown, there is a variety of different reasons for the way people respond to a Likert-type item such as those found in the SCN quantitative instrument. For instance, Aikenhead (1988) found an ambiguity of about 80% in understanding Canadian 17 year-old students' ideas when expressed in a Likert-type format. The ambiguity was reduced to about 50% when students wrote out their ideas in a free response format. Although these written responses — qualitative data — provided a clearer understanding of what our respondents thought, a much smaller range of topics could only be addressed within a reasonable length of time. As anticipated, however, the SCN qualitative instrument did afford considerably more insight into respondents' ideas than did the SCN quantitative instrument. These richer qualitative responses allowed us to formulate appropriate interview questions that probed into fundamental positions that teachers held about Aboriginal knowledge, science, students' success or lack of success with school science, etc.

The ambiguity in understanding what people think is reduced to below 5% when using an interview format (Aikenhead, 1988). Thus, we designed a semi-structured interview instrument (protocol) into our research study (Appendix 3). As mentioned above, the interview questions emerged from the issues identified by the responses to the quantitative and qualitative SCN instruments. An hour of discussion between an interviewer and a teacher provided us with the clearest, most qualified understanding of teachers' views on the connection between science and culture. Consequently, more credence can be placed in the interview data than in the qualitative and quantitative data, respectively. Nevertheless, some of the qualitative and quantitative data will provide a useful context for discussing some of the interview data.

In summary, we collected our data using three different methods: (1) a Likert-type SCN instrument that produced quantitative data (a 67 item questionnaire), (2) a free-response SCN instrument that produced qualitative data (a 10 item questionnaire), and (3) a semi-structured interview that produced qualitative data we refer to as "interview data."

Participants and Data Collection

On the advice of the Gabriel Dumont Institute and First Nations educators, six educational jurisdictions were identified across northern Saskatchewan (Table P1). In January, the leader of each jurisdiction (usually the Director of Education) was contacted by letter outlining the study and requesting that we might invite some science teachers to participate anonymously. We asked for teachers who taught grades 7 to 12 science to Aboriginal students or who had a science class with a significant number of Aboriginal students. For five educational jurisdictions, lists of teachers were provided. The sixth jurisdiction provided a list of schools to contact.

Table P1 fits here. See Appendix 6

To each teacher nominated by his or her Director of Education (or equivalent), we sent a one-page description of our study along with a short letter stating that we would soon contact them by telephone to talk about the project and ask them to volunteer. The telephone conversations occurred in late February and early March. As a result, 59 science teachers agreed to participate. Fifty quantitative and nine qualitative instruments were then mailed out, along with an ethics contract (a contract that followed SSHRCC guidelines and was approved by the University of Saskatchewan's ethics committee; see Appendix 4). The nine qualitative instruments were randomly assigned. Follow-up telephone calls were made to encourage responses. Table P1 shows that 25 quantitative and 7 qualitative responses were received, a 54% overall return rate. (This reply rate is discussed later in the "Findings" section.)

The last phase of the SCN project consisted of interviewing 10 teachers. A semi-structured interview protocol was designed, guided by a preliminary analysis of the quantitative and qualitative survey responses. The interview protocol (Appendix 3) probed salient issues identified by teachers as important to understanding the cultural aspects of Western science, and its connection to the Aboriginal culture of their First Nations and Métis students. The teachers who volunteered to be interviewed were sought out on the basis of (1) diversity representing various First Nations and Métis communities, (2) Aboriginal background, (3) diversity in teaching situations, and (4)

proximity to Prince Albert. Table P1 identifies the 10 interviewees by educational jurisdiction. The participants' personal identities are held in strict confidence, of course. Interviews were conducted in May by co-researcher Bente Huntley who audio taped and transcribed them. We returned the transcriptions to the participants for them to read, and we asked teachers to change any part of the transcript to guard their anonymity and to clarify or correct any point they made. This procedure ensured that the transcript conveyed their views in the most valid manner humanly possible.

Our results are *not* generalizable to other teachers of Aboriginal students. In keeping with the tradition of the interpretive research paradigm, we expect that the teachers' views documented in our study will be conveyed in this report clearly enough to the reader that he or she can decide how well our results inform the reader's situation.

Research Team

Dr. Glen Aikenhead (non-Aboriginal), College of Education, University of Saskatchewan, has 25 years experience with student-centred research into: student and program assessment and evaluation, curriculum materials, instructional strategies, teacher practical knowledge, and curriculum policy. His recent research focuses on cross-cultural science education (Aikenhead, 1996, 1997).

Mrs. Bente Huntley (Aboriginal), science education instructor with SUNTEP Prince Albert, graduate student at the University of Saskatchewan, 8 years experience in science education, is currently finishing a Masters of Education program focusing on the development of First Nations content material for science courses in Saskatchewan schools.

FINDINGS

The SCN project has three research objectives: to develop an SCN instrument, to convey current beliefs of some science teachers, and to identify a network of potential R&D collaborators. Given the interpretive nature of our project, it is important to know something about the teacher participants, because this information will be critical to the reader's interpretation of the study's quantitative, qualitative, and interview results. Consequently, the first topic addressed in this "Findings" section concerns the participants themselves. The next two topics will deal with research objective 1 (the development of an SCN instrument) and objective 2 (beliefs of the science teachers). Research objective 3 — the identification of people who might become involved in a future project — will not be reported in this public document. The anonymity of our participants requires that no one be identified. As well, the list of potential future participants will grow and change as the present project is disseminated throughout the province. For instance, our interview data uncovered an innovative project being implemented in one of the isolated northern schools during the 1997-98 school year. Its teachers will certainly be contacted when a collaborative R&D project is designed (future funding).

Participants

As described earlier, our SCN project attempted to discover a diversity of viewpoints. Thus, our sampling aimed to encompass a broad scope of participants — a representative sampling of teacher viewpoints — rather than aiming for a statistically valid random sampling of teachers. Our results were never meant to be generalizable, but certainly they are expected to be transferable to some Saskatchewan schools. The reader is reminded that the 54% overall response rate may influence the content of the results, especially the quantitative results.

Information describing the participants is reported here in terms of: (1) teachers who responded to the quantitative instrument, (2) teachers who responded to the qualitative instrument, and (3) teachers who were interviewed.

Quantitative Respondents

The participants responding to the quantitative SCN instrument provided biographical data. These data are found in Table P2 as bold-faced tallied responses placed where the teachers' individual responses were originally made in Section A of the instrument. Although both sexes were well represented, there were relatively few Aboriginal science teachers in the group. Diversity within the group of respondents is evident in many of the items in Table P2; for example, according to item 14, the participants represented diverse communities. The responses to item 9 (principal occupation) are worth noting because the results indicate that 10 of the 25 participants taught science but did not identify themselves as science teachers.

Table P2 fits here. See Appendix 6.

Qualitative Respondents

The biographical information on the seven teachers responding to the qualitative form of the SCN instrument is summarized in Table P3. The respondent's identification number becomes important because in the "Beliefs of the Science Teachers" section (below) these people are extensively quoted. The reader may wish to interpret those quotations in light of the teachers' biographic data.

Table P3 fits here. See Appendix 6.

As mentioned earlier, nine qualitative instruments were sent out to teachers selected at random from the original list of 59 teachers. It is interesting to note that the return rate for the qualitative instrument was rather high — 78%. This indicates that teachers were more predisposed to participating in the SCN project when they could respond in their own words to 10 items, compared to responding in a Likert-type mode (strongly agree, agree, not sure, disagree, or strongly disagree) to 67 items in the quantitative instrument. In addition, there was a higher response rate from female teachers for the qualitative instrument compared to the quantitative instrument.

Otherwise, however, the biographical make up of the qualitative respondents was similar to that of the quantitative respondents. For instance, only one respondent (number 60) was Aboriginal.

Interviewees

As we argued earlier, the richness and clarity of interview data encouraged us to place much more confidence in the interview data than in the quantitative and qualitative data. Consequently, the biographical information describing the ten interviewees is crucial to understanding and interpreting their ideas. This biographical information is found in Table P4.

Table P4 fits here. See Appendix 6.

Purposefully, Aboriginal science teachers were sought out to give voice to perspectives found in First Nations and Métis communities. Thus, four of the ten interviewees were Aboriginal teachers (Betty, Alice, Joe, and Ted). Another purposeful characteristic of all ten participants was their diverse teaching situations: two teachers (Betty and Doug) worked in an urban setting, two teachers (Larry and Rose) taught for the Northen Lights School Division, while six teachers (Jack, Alice, Brent, Joe, Ted, and Gary) were in band operated schools (see Table P1).

While Table P4 provides objective biographical data, the reader may want to know each participant more subjectively. This information was gleamed from the interviews by paying attention to key incidents, defining metaphors, or pervasive themes, supplied by the interviewees themselves. These data are found in Table P5.

Table P5 fits here. See Appendix 6.

Both Tables P4 and P5 will likely be very helpful to the reader when interpreting the interview data in the "Beliefs of the Science Teachers" section below.

As with the SCN instrument respondents, the interviewees and the researchers jointly signed

an ethics contact that assured their anonymity and guaranteed that they had control over the information gathered. A copy of this ethics contract can be found in Appendix 4.

Development of an SCN Instrument

The written and oral feedback from participants about our quantitative instrument led us to revise the instrument in three ways: (1) we deleted the response section requesting teachers to convey the viewpoint generally held by their colleagues (in order to reduce the overall effort required to respond to the instrument in general, to avoid the unease felt by a few participants over reporting the views of their colleagues, and to avoid the perplexity felt by several teachers who did not know the views of their colleague); (2) we reduced the number of items from 67 to 44 by deleting items that either seemed redundant (basing our judgement on patterns in our quantitative responses) or addressed less relevant issues (basing our judgement on the qualitative and interview results); and (3) we edited a few items to increase their clarity. Consequently, a shortened version of a Saskatchewan SCN instrument is now available for future use. It might help to identify groups of teachers who share similar views on the connection between their students' culture and the science taught at school. A copy of this final Saskatchewan version of the SCN instrument may be found in Appendix 5.

The quantitative form of the SCN instrument could be used to compose a qualitative form of the instrument by selecting a number of items and requesting teachers to write out the reasons for their responses. The selection would be based on the topics of particular interest to the people composing the qualitative instrument. Past experience indicates that a maximum length for such an instrument is about 10 to 15 items (Aikenhead and Ryan, 1992).

Beliefs of the Science Teachers

As described above, the research results came from three different methods we used to collect our data: an SCN instrument that produced quantitative data (the 67 item questionnaire), a free-response SCN instrument that produced qualitative data (the 10 item questionnaire), and a semi-structured interview that produced very detailed qualitative data which we refer to as "interview data". A total of 42 volunteer teachers from across the northern half of Saskatchewan (Table P1)

participated in these three phases of the research. Twenty-five teachers responded to the quantitative instrument, seven teachers responded to the qualitative instrument, and ten teachers were interviewed. Biographical details of the three groups are found above, in the section "Participants".

The content of SCN quantitative and qualitative instruments were organized around the following five topics: (A) science, (B) science and culture, (C) science and indigenous knowledge, (D) culture, and (E) teaching and learning science. These topics were addressed in the interviews but with much less structure than in the instruments. The content and organization of the interviews -- the interview protocol -- emerged from the issues raised in the qualitative responses, and to some degree from issues raised in the quantitative responses. The interview protocol is found in Appendix 3.

The quantitative results from the 67 item instrument are shown in Tables A, B, C, D, and E; all of which are found in Appendix 7. These quantitative results will be drawn upon selectively from time to time to give the reader a broader context in which to interpret the interview data.

As expected, the interview data produced our most credible results, and consequently these data will be central to our discussion of the science teachers' beliefs. Nevertheless, some of the qualitative and quantitative results enhance these interview data and will be reported where appropriate.

The views expressed by the interviewees gave considerable clarity to a wide range of ideas that had been expressed in the quantitative and qualitative data; ideas about the connection between science and culture, in the context of teaching science to Aboriginal students. The interview data were organized around nine general questions:

1. What is culture?
2. What is science?
3. What is the status and use of Aboriginal knowledge in science and science classrooms?
4. Does the possession of Aboriginal knowledge inhibit students from learning science?
5. If Aboriginal students do master science: Do they loose something valuable from their own culture? Does the science now dominate their thinking? Are they somehow alienated from their own culture?
6. Is there a connection between Western science and Euro-American culture?

7. To what extent is science a foreign culture to Aboriginal students?
8. Why do Aboriginal students tend to avoid higher level science courses and science related careers? and
9. In the context of teaching science to Aboriginal students, what is a science teachers primary responsibility?

Each of these nine points is addressed in turn, beginning with the teachers' views of culture.

Culture

Our interviewees generally agreed that culture was a way of thinking, of viewing the world, and of interacting with the world; in short, a way of living. Betty and Alice mentioned moral and spiritual dimensions to culture. Rose expressed her understanding as "who you are and knowing where you come from" (line 24 in her transcript) and not just the customs and traditions of a people. Gary defined culture by repeating what he had heard his Aboriginal colleagues say, "our way" (line 148 in his transcript). Some participants talked about different subcultures and about how culture changes depending on the circumstances.

Similar to our interview data, the quantitative responses (Table D, Appendix 7) generally indicated agreement that culture was "the life style of a people" (item D1) or "a system of meaning" (item D3), phrases taken from anthropology (Geertz, 1973). However, most respondents disagreed with a broader idea that culture is "everything that is not nature" (item D2). The changeability of culture was acknowledged by a large majority (item D10). It is also interesting to note that about one half of the teachers did not recognize, as many educators do, that culture is embedded mostly in language (item D7; Stairs, 1995).

In summary, it would seem that almost all the teachers held similar ideas about what culture is. This finding helps us understand what teachers meant when they talked about culture.

Science

No one attempted to define science during the interviews. However, the word came up on many occasions, of course (see Table P5 for some examples). From these occasions it became evident that different people had very different ideas about what "science" means, and these

meanings would shift when the context changed. Depending on the context, the following meanings of science could be found in the interview data. Science is:

1. any knowledge about nature irrespective of the knowledge system used (e.g. "science is everywhere," "children learn science on the trap lines," and "Aboriginal science").
2. the canonical knowledge, skills, and values of Western science as found in university science courses and in school curricula.
3. a school subject to be passed for credit.
4. processes and products usually identified as technology by the academic social science community.
5. a subculture, or an aspect of Euro-American culture.

One person (teacher number 60) writing a free response to the qualitative instrument distinguished between meaning numbers 1 and 2 by putting the word "science" in quotation marks to refer to meaning 2. It is interesting to note that she, the only Aboriginal who responded to the qualitative instrument, often used the verb "sciencing" when referring to what occurred in her 7th grade classroom.

One entire section of the quantitative instrument was dedicated to ideas about science (Table A, Appendix 7). The two most popular descriptors of science were "exploring the unknown" (item A2) and "carrying out experiments" (item A3). At the same time, however, a majority of respondents equated science with technology (64% in item A4, and 80% in item A5); that is, the teachers in our study associated science with activities and goals normally considered to belong to technology (meaning number 4 above). Thus, the phrase "interaction of science and culture" will mean the same thing as "interaction of technology and culture" for most of the teachers. This was also found to be the case in the interviews. This inaccurate notion of science is contrary to the view expressed in Saskatchewan's common essential learning called technological literacy. The scholarly social science literature consistently points out that science and technology are quite different enterprises, though they interact considerably (Collingridge, 1989; Ziman, 1984).

A majority of teachers (72%) responding to the quantitative SCN instrument acknowledged that science could be "a rational perceiving of reality" (item A7), an expression which Ogawa (1995) used for definition number 1 above. As Table A shows, the quantitative data also indicate that many

teachers do not consider science to have a male bias (item A10) contrary to most views found in the social science literature (Rose, 1994). The data from item A10, however, are highly ambiguous because we do not know which of the five definitions of science listed above were in the minds of the respondents when they answered item A10. (This problem of ambiguity in the quantitative data was discussed elsewhere in this report in the method's subsection "Research Instruments".)

In summary, the reader must be vigilant and sensitive to at least five different meanings of science found in teachers' statements about the connection between *science* and culture.

Status and Use of Aboriginal Knowledge

Rose and Alice, a non-Aboriginal and Aboriginal teacher respectively, put a very high premium on incorporating Aboriginal knowledge into the school program, more than most other interviewees. "It builds student self-esteem," Rose claimed (line 48 in her transcript)[2]. Their incorporation of Aboriginal knowledge drew principally upon community elders as the educational resource. Because the number of available elders is limited, it is difficult to access this valuable resource (Alice, line 28). This problem is coupled with the fact that most print and audio-visual materials known to the teachers are relevant to *American* First Nations students, not to Cree, Dené, or other Saskatchewan Aboriginal students. This lack of resources was cited by most of the other participants as the main reason that only a token amount of Aboriginal knowledge was introduced into their science programs.

Aboriginal participant, Betty, grew up in a central Saskatchewan community. She, too, put a high priority on incorporating Aboriginal knowledge into her science classroom so students could make connections to their lives and culture while engaging in hands-on "sciencing." However, the community in which Betty was teaching was not the community where she grew up. that made a world of difference to how much Aboriginal knowledge she could incorporate. In her words:

> I work with an Aboriginal teacher who is always bringing in people. She's older than me and she's lived here forever and knows all these people personally. I don't actually live here;

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[2]Each line in a person's transcript is numbered. The numbers that appear in the text (e.g. 48) refer to the line number in the person's transcript.

close to this area. I don't know of the elders personally. I don't feel all that comfortable approaching them when I don't know them really well. I think there is a lot of non-Aboriginal teachers who feel that way. (Betty, 350-356)

Her advice to herself is to have students learn the community's First Nation knowledge on their own and then teach the class what they had learned.

> And if they [the students] don't happen to be very knowledgeable about their culture, then that gives them an opportunity to approach somebody within their culture like an elder and ask some questions. Then they have a twofold responsibility. One is what they learned from that elder which they might have to apply to themselves somewhat. The other is to bring the knowledge back to the classroom to share with others. (Betty, 327-333)

On the other hand, Alice (who has taught five years in her community) took more personal responsibility to learn from resource people, "If I couldn't find someone to come in, I would go and ask someone and then bring that back; tell the kids what I've learned" (Alice, 34-36). Nevertheless, as mentioned just above, Alice found it difficult to get hold of resource people and so she rarely made use of them in her classroom (28). Whereas Alice's school made a conscious effort to teach both Western science and First Nations knowledge in science classes, Betty's school did not have that commitment, and hence Betty felt the responsibility falling almost all on her shoulders.

Jack (lines 12-23) and Brent (line 230) were the only teachers interviewed who distanced themselves and their teaching from Aboriginal knowledge. Several of the other teachers mentioned that their classroom was the only science classroom in the school where Aboriginal knowledge was welcome. The picture emerging from the interviews is an expressed openness to include Aboriginal knowledge in the science program (the Saskatchewan science curriculum was cited by several teachers as encouraging it), but in practice little or moderate headway is being made except for a few unique instances (Rose and Alice).

Other problems mitigating against the incorporation of First Nations knowledge into science instruction for some communities were identified by Brent and Joe. The Aboriginal students in their communities are so disconnected from their First Nations culture that incorporating Aboriginal knowledge into the science classroom would not really seem relevant to them. (Betty concurred with their observations but had a different response – get students to learn from the elders and then teach

the class -- as described above.) Joe pointed to the 50:50 split in his community among the Aboriginal parents, where half wanted Aboriginal knowledge taught in school while the other half was against it (48). Nevertheless, he felt that Aboriginal knowledge is very evident in his school's science classrooms. Joe valued his Aboriginal knowledge as being scientific. However, several teachers mentioned that their students did not value their own Aboriginal knowledge as worthy of equal status to school science (e.g. Ted, 126).

Gary and Ted both suggested that the Anglican church had succeeded in almost eliminating First Nations spirituality in the community where they presently taught. Traditional ceremonies were conducted in secret, if at all. Consequently, when bringing Aboriginal knowledge into his classroom, Gary felt pressured to exclude references to spirituality (216), but he saw value in considering both Western and Aboriginal views because it develops critical thinking skills (570).

Rose made the observation that elders are reluctant to talk to groups of high school students in classrooms because students at that age are considered to be on their own, too old for this type of group instruction from elders (307). This might help explain some of the perceived lack of resources expressed by high school science teachers.

Both the qualitative and quantitative SCN instruments specifically asked if "Science and Aboriginal knowledge should both be taught in a science classroom" (item E9). The quantitative responses in Table E (Appendix 7) show that 15 teachers agreed, 4 disagreed, with 6 not being sure. (By changing "should" to "can"-- item E8 -- responses changed to 22 agree and only 1 disagree.) Similarly 13 agreed and 4 disagreed with the idea that science and Aboriginal knowledge are compatible (item E5). The qualitative responses give us various reasons for teachers agreeing with the statement. These are shown in Table E9. In these written responses, one can detect different meanings of science among the teachers, and can detect problems already identified by the interview participants (discussed above).

Table E9 fits here. See Appendix 8

Aboriginal Knowledge Inhibits Learning Science

One major and consistent finding in science education research over the past 20 years is the recognition that students' preconceptions (their everyday common knowledge) often inhibits their learning science because their preconceptions make more sense to them than many of the counter-intuitive concepts found in science. Consequently, students resist re-conceptualizing (or rejecting) their prior knowledge (Driver et al., 1994). Instead of learning scientific concepts meaningfully, many students will play "school games" to give teachers the impression that they have learned the concepts. By following certain rules, called "Fatima's rules" (Aikenhead, 1996; Larson, 1995), students can hand in lab reports or pass exams without learning the key scientific concepts. This meaning of science was captured by meaning number 3 listed above in the section "Science". Scientific concepts, while a central focus to science teaching, are not the only content to be taught, however. The Saskatchewan science curriculum lists seven types of content, only one of which is key scientific concepts. In any case, there is a general recognition in the science education research community that for many students their commonsense knowledge generally inhibits their learning science.

With this background in mind, we can look at the quantitative responses to item C6 (Table C, Appendix 7), "Students' belief in everyday common knowledge inhibits their learning science". Interestingly, 18 teachers disagree, with only 5 agreeing. We need to keep in mind that different responses are likely based on different meanings of science, and thus these results are rather ambiguous. On the other hand, the discussions in the interviews give us some insights into the reasons that 18 teachers disagreed with item C6. These discussions, in which "everyday common knowledge" was interpreted as "Aboriginal knowledge", are summarized here.

Most of the 10 interviewees would have likely "disagreed" with item C6 as well, but their reasons would vary considerably. For instance, Joe who did not separate the two knowledge systems in his mind (scientific and Aboriginal), believed that an individual can take what he or she can from each type of knowledge system (140). Doug explained that Aboriginal knowledge can help his students learn science when the science content is used to explain Aboriginal ideas (233). Gary claimed that Aboriginal knowledge is "the best teaching tool you could use" (355) and cited the resource material *Practising the Law of Circular Interactions*. Gary's approach would be to teach

critical thinking skills first (361), because critical thinkers will not see a conflict between science and Aboriginal knowledge. He added: If students "make no effort to get involved in the information, they'll be ignorant" (369); thus, there was no problem of Aboriginal knowledge inhibiting students' learning of science. Brent recognized that traditional values do conflict with chemistry theory but pointed out that one can *understand* an idea (for the purpose of passing tests and getting to university) but not *believe* it. The distinction between understanding and believing a scientific idea seems to be fundamental to learning science. Gary and others also alluded to this distinction.

Along similar lines of thought, Alice recognized the potential conflict between scientific reductionism and the commonsense holistic way of First Nations students (70-77), but she claimed that this potential conflict did not inhibit students in her community from learning science (117). She advised teachers to relate science to kids' interests, to engage them in activities in which they learn science skills, and then have kids transfer those skills to a written assignment (228).

Rose gave a much different reason. Learning science is not inhibited in her community because many students do not know their traditional knowledge in the first place. Instead they believe the Western culture, a pervasive influence of the Catholic church she claimed (109-123). The problem is also blamed on the social institution of schooling: students are "confused about their own traditions and the whole Western world coming in with its institutionalized education" (219-221).

On the other hand, Jack cited students' lack of discipline and lack of language and math skills as the inhibitors to learning science (92-105). Larry tended to agree with Jack (472) but stressed a much more fundamental inhibitor — a lack of family support for school learning (414-422).

And finally, Betty provided many reasons and conditions that would either cause or avoid inhibition (some have already been mentioned): lack of knowledge of their own culture (109); the need to relate science to students' lives (115, 185, 404); the need for hands-on activities (128); and science is "just another point of view" so why learn it? (199). Betty also pointed out that instruction that relies on the textbook and note writing inhibits students' learning (125), as does science content that explicitly rejects First Nations beliefs (248). According to Betty, learning will be facilitated if a teacher "meshes" First Nations and science knowledge (219) making many connections between the two (255). She claimed that the two biggest inhibitors to learning science are disruptive students

when they play at science (486), and students not having the skills or desire to write an intelligent response about what they were doing in a hands-on activity (488).

When the issue of Aboriginal versus scientific knowledge arises, as it did in the discussions just above, different viewpoints begin to surface about how to handle two different, and potentially conflicting, knowledge systems. At one extreme is Betty's approach of "meshing" the two knowledge systems together, while at the opposite extreme is Brent's approach of segregating the two so someone can understand one system without necessarily believing it. These two extremes (and various positions in between) comprise a theme that pervades other issues about the science and culture nexus -- different ways of resolving potentially conflicting knowledge systems. The theme will be illustrated further in sections below, and will constitute a significant conclusion to the SCN project.

Consequences to Mastering Science

Closely related to the discussion over two different knowledge systems (Aboriginal and scientific) is the issue of what happens to Aboriginal students who succeed or excel in their science courses: Do they lose something valuable of their own culture (item E14)? Do they necessarily become alienated from their own culture (Items B4 and E6)? and Does a scientific way of knowing dominate their own thinking (items E7 and B3)? Underlying these questions is the fear of assimilation into Western culture at the expense of one's Aboriginal culture, a fear well founded, given the pervasive negative experiences of Indigenous Nations world wide (Baker and Taylor, 1995; Battiste, 1986; Ermine, 1995; Simonelli, 1994; Suzuki and Oiwa, 1996). Because science tends to be a Western cultural icon of prestige, power, and progress, its subculture permeates the culture of those who engage it (Dart, 1972; Jegede and Okebukola, 1990, 1991; MacIvor, 1995; Ogawa, 1995; Pomeroy, 1994).

However, the science teachers participating in our study tended to reject any negative consequences to Aboriginal students' learning science, as shown in Table Z1 (selected quantitative responses from Tables B and E in Appendix 7). Most participants felt that students: would not lose something valuable of their own culture (item B4), would not have to reject their Aboriginal ideas (item E6), and would not have foreign cultural values imposed upon them (item E7). However, a

substantial majority (18 out of 25 teachers, 72%) believed that science would often dominate a student's way of thinking (item B3), a domination that did not apparently occur at the expense of an Aboriginal way of thinking.

Table Z1 fits here. See Appendix 8.

These results are clarified by the qualitative responses to item B4 (Table B4) which appear to mirror the quantitative results. Only one respondent (number 60) thought that science does alienate people from their own culture but "only if one allows it". Rigid science teachers were cited as the usual cause of such alienation. On the other hand, the other six respondents disagreed, but for several very different reasons as shown in Table B4.

Table B4 fits here. See Appendix 8.

The interviews amplified these ideas. The four Aboriginal teachers (Ted, Joe, Betty, and Alice) will be considered first. Ted maintained a basic belief about learning: "You don't have to lose something when you gain something" (412). Science will enhance what you already know. He attributed alienation not to science but to the Anglican church that nearly eliminated traditional spirituality from his community, though this spirituality is slowly returning (144).

Joe was not as optimistic as Ted. Joe warned of the danger of losing something valuable from Aboriginal culture and the danger of science dominating one's thinking, if it was not watched and guarded against (144-154). One way to guard against it is to constantly differentiate between each set of beliefs, Aboriginal and scientific (157).

Betty and Alice both emphasized students' individual differences; that is, the consequences to mastering science will be different for different students. Some students will lose something valuable of their own culture if they master science, but others will not. Betty and Alice identified various types students: those "keeners" who naturally and easily catch on to science (Betty, 227),

those "keeners" who are curious but have to work at understanding science (a group Betty identified with, 230), and those who just memorize to get through by playing Fatima's rules (Alice, 180). Alice noted that the degree of domination of science will vary from community to community (160). She also expressed a fundamental tenet to her idea of learning: "What students believe in has to be affirmed some way. You can't separate it" (266). Alice's view reinforces Betty's idea that the two knowledge systems (scientific and Aboriginal ways of knowing) need to be meshed; a view that appears to contradict Joe's belief in differentiating between each way of knowing.

Brent (483) thought that scientific knowledge would dominate students' thinking unless they made a conscious effort to support another view, an effort acknowledged by Brent to require considerable attention. Doug presented a similar view by emphasizing the idea that to dominate one's way of thinking does not necessarily mean that one is alienated from one's culture (363).

Jack, who claimed to know little science but was impressed by people who did, repeated the view that learning science expands our horizons "in all directions" (150) and so learning science does not alienate students from their own culture (164). To expand one's horizons was associated with joining an elite group (and for Jack, an illusive group) who understood science (142). Learning science would add to what students already knew from their own culture (130).

Rose believed that the assimilation into Western culture (mostly through technology such as TV) has already generated a "Eurocentric way" (137) in the minds of Aboriginal students who therefore see science as commonsense logical, and as a consequence, science dominates their thinking (192).

Gary cited his own experience of learning Aboriginal knowledge over the years without it dominating his thinking. He expects that Aboriginal students can handle scientific knowledge just as he handled Aboriginal knowledge (428). Teaching science "properly" (with an emphasis on critical thinking) will ensure that nothing valuable is lost from one's culture. Again, Gary cited the negative influence of the Anglican church, rather than science, as the cause of native alienation in his community (158).

A very different picture was painted by Larry. He too disagreed that mastering science would cause students to lose something valuable of their own culture (40), but Larry also talked about students switching back and forth between the two ways of knowing. Each way of knowing was like

having ideas "in different pockets" (206, 288, 305). Here Larry articulates a fundamental view of *separating* the two knowledge systems. He goes on to argue that science dominates one's thinking, not because of the potency of scientific knowledge, but because Western culture strongly dominates other cultures, period; thus, Western culture, not science, marginalizes First Nations peoples (65). Larry then returned to his thesis that a strong family or a strong culture/education protects students from losing something valuable from their own culture and from becoming alienated from their own culture (66, 287, 353). According to Larry, individual differences and community circumstances are influential, an idea that found support from Betty and Alice.

In summary, various interviewees pointed to various cultural features in their community *other than school science* to explain any alienation of students from their Aboriginal worldview. In addition, epistemologically conflicting ways of knowing were perceived as holistically accumulative in understanding natural phenomena; or alternatively, as distinguishable and parallel ways of knowing, between which people can move back and forth in a way similar to moving from one pocket to another (to use Larry's metaphor).

The issue of assimilation surfaced in the qualitative responses to item B15. The results are displayed in Table B15. Again, a variety of ideas illustrated differing viewpoints on how to deal with potentially conflicting ways of knowing. Some of the viewpoints ignored the conflicts altogether by simply assuming that knowledge is accumulative in a value-free manner (teachers 10, 21, and 60), while others react to the conflicts either by separating the two ways of knowing (teacher 39) or by supporting the need for assimilation of First Nations students (teacher 116). In addition, the term "science" was used by teacher number 27 to mean any knowledge of nature, which by definition tends to erase any underlying conflict between Aboriginal and scientific knowledge.

Table B15 fits here. See Appendix 8.

Western Science and Euro-American Culture

Historian and social science researchers have argued that Western science is intimately related to Euro-American (Western) culture (Maddock, 1981; Pickering, 1992; Pomeroy, 1994; Rashed,

1997). Scientists share a well defined system of meaning and symbols with which they interact socially (a standard definition of culture used by cultural anthropologists; Geertz, 1973). Because the system was institutionalized in Western Europe in the 17th century, it became predominantly a white male middle-class Western system of meaning and symbols (Mendelsohn, 1976; Rose, 1994; Simonelli, 1994).

This cultural view of science, however, was acknowledged by only a half of the science teachers in our study. The quantitative responses were evenly split between agreeing and disagreeing with item B7 ("Science is often seen as a subculture of Western culture.") and item B13 ("Western beliefs, values, and conventions are an implicit aspect of science.").

A connection between science and Euro-American culture was never once volunteered in any written response or in any interview discussion related to two major issues analyzed earlier: Does Aboriginal knowledge inhibit students from learning science? and What are the consequences to one's own culture of mastering science? The connection between Western science and Euro-American culture is not a salient issue, according to the science teachers in our study.

The interviewer explicitly raised the topic late in a number of interviews. Although teachers agreed there was a connection between Western science and Euro-American culture, their agreement seemed muted by their reluctance to discuss the topic further, either when it was raised as a point of discussion or in the context of the possible conflict between Aboriginal culture and scientific knowledge. Joe (121) did mention that science was one aspect of mainstream Western culture. Rose (136) stated that science was part of the larger Eurocentric culture that has changed Aboriginal culture. Doug (99) rephrased the interviewer's expression when he said that science is a subculture of Western culture, as viewed by Westerners. Betty (158) represented science by the personage of Albert Einstein, saying science is almost a subculture of Western culture. Western science is the knowledge of Western culture (109). Betty added, in a different context (269), that scientific ideas may be legends for Western culture. It was Jack who gave the most convincing argument when he pointed out (74) how strongly science and Western culture have been connected over the past 500 years, and how he has personally experienced change in his Western culture because of scientific (read "technological") advances.

The connection between Western science and Euro-American culture described here seems

more intellectual than practical in the context of classroom practice. In the day to day issues posed by First Nations and Métis students learning science, the cultural status of science seems to have little currency in teachers' reflections on these practical issues at hand.

Science as a Foreign Culture

Another way of approaching the connection between science and culture is to discuss item E15: "For many students, learning science is like going into a foreign culture". The 25 teachers who responded to the quantitative instrument were split on this issue (12 agreed, 8 disagreed, and 5 were not sure; Table E in Appendix 7). The interviews help clarify this reaction.

We first turn to Gary who argued that science should not be foreign to Aboriginal students. Science is everywhere, he maintained. Aboriginal people "practise chemistry all the time and understand it" (179). "People will say, 'Science is not our way,' but it really is, only in different words" (350). Here we recognize a meaning of science (meaning number 1 listed in the earlier section "Science") that, by definition, makes no distinction between Western scientific ideas and Aboriginal knowledge of nature. To the question "Is science a foreign culture?" Gary responded (432), "No, they don't have to be separate," but he also said "yes" (500) if science was not taught properly (a theme expressed by Gary in earlier quotations).

Other interviewees stressed the role of language in school science. Ted (585) claimed that the biggest impediment to learning science was scientific terminology, and that the language of science was particularly challenging for ESL (English as a Second Language) students. Doug echoed this problem and called science "a third language" (291). Betty mentioned the many terms to be memorized in science classes. "Throwing words and formulas at students intimidates them" (318). She added, "It's like that foreign language kind of thing. Foreign culture. All of a sudden you're totally immersed in it. Perhaps not enough relationship to real life to make it through the whole thing [high school science]" (552-555).

On the other hand, Alice and Joe commented on the fundamental differences between scientific and Aboriginal knowledge. Alice (54) talked about the reductionist approach to nature found in science classrooms and how this conflicts with a holistic approach found in a First Nations cultures. Joe (375) reminded us of the Elder's respect for Mother Earth inherent in their knowledge

of nature, but not inherent in scientific knowledge.

Jack equated "foreign" with "difficult" (159) in keeping with his view that science is difficult for him (283), and therefore he agreed that science is like a foreign culture.

Larry reiterated his position that the foreignness of science depended on a lack of solidness of the family (426-440), coupled with the student's lack of background knowledge, skills, and a love of learning (460). If there was a strong family support for learning school science, science classes would not seem foreign to students. In Larry's view, therefore, student difficulties had little to do with the differing fundamental values that Alice and Joe discussed, or the language demands of science articulated by Ted, Doug, and Betty.

Rose gave a particularly thorough response, in some cases underscoring the points made by other teachers. Science will not seem foreign to her students because they have already become Westernized themselves (136). She attributed any foreignness of school science to the Western institutionalized form of schooling, in which science plays its part. In other words, Western *schooling* conflicts with Aboriginal traditions (220). In addition, school science tends to be overloaded with vocabulary (248) and is usually taught in a student's *second* language (238). Rose advised connecting school science content with students' real life worlds to overcome conventional disconnectedness between school science and Aboriginal students (236).

Students' Avoidance of Science Courses and Careers

As we read many of the teachers' arguments supporting the view that science is not any more conflicting or foreign to Aboriginal students than it is to their non-Aboriginal counterparts in other schools, the question comes to mind: Then why are there so few Aboriginal science teachers, scientists, and engineers? Why do so few Aboriginal students continue to take science in high school and university?

Some of the teachers interviewed (Alice, Rose, and Larry) were really not sure at first. Alice (324) suggested it might depend on the community because science is not stressed in some band schools, but also, some students seem intimidated by the required skills in science (195). Rose surmised a fear of math and a lack of confidence (178). She also discussed what "science" meant to students: a subject to be passed ("a marks motivated system", 392) and not a rational perceiving of

reality (a meaning making system connecting ideas together, 404), and who wants to make a career out of an artificial school subject? (211) Rose added that her students' facility with English was a major barrier (273), as well as the boring "taking notes and listening to lectures" (378) approach in high school science.

Betty felt that science had been used in the past to reject First Nations knowledge, and this would discourage First Nations students from taking science seriously (284). Her view found support in Gary (480) who suggested that science careers are associated with the White power structure of Canada. Careers are rejected by Aboriginal students who feel their people have been abused. Betty added that the textbook, note-writing approach to teaching science also turned kids off (292, 546), though she thought that this turn-off was equally true for non-Aboriginal students (288).

Ted explained that high school science is associated with going to university. University life is quite a change for students (leaving the safety of home to go to the big city), too much change to be comfortable (453). Thus, there was little incentive in general for his students to be interested in a science or engineering career.

Joe commented on the conflict between the scientific value of questioning everything and the traditional home value of accepting things as they are (166). The conflict increases an Aboriginal student's discomfort with science as a life career.

Intimidation and students' fear of failing were mentioned by Jack (168) when he commented on how university science content had been pushed into the high school curriculum. Brent as well mentioned intimidation and fear (516) but agonized over how students who do have the necessary skills do not realize they can do science (799). In his eyes, students do not see the connection between scientific knowledge and their real life (552). In addition, students need more self-confidence (530). Brent hypothesized that maybe a stigma has been attached to science due to a tacit conflict between science and traditional ways (537).

On the other hand, Larry suggested that the problem of students avoiding high school science is not cultural but rests with the student's family (422). "Kids who come from very solid backgrounds do well in everything" (432). To move on in science, kids need knowledge and a love of learning (459). Nevertheless, it was a puzzle to Larry why so few of his high school students will attend university (375).

Gary's reason for so few Aboriginal students attending university was the poor prospects for a good job for university graduates (473). Employment is more secure through the trades, not through academics (482). High school science seems too hard and too abstract for all students (488). When science careers prove more useful to students, more students will follow those careers (440).

Doug listed several reasons for students avoiding high school science: (1) the negative influence of their peer culture (158), (2) the lack of First Nations role models in science (380, 399), (3) the challenge of language skills (373), and (4) the lack of validation for their own cultural experiences in the science curriculum (402).

It is interesting to note that in all the discussions presented in this report, teachers tend to reiterate the same theme to explain different issues about school science and the problems faced by Aboriginal students. It is also significant to note that the potential cultural conflicts between science and First Nations knowledge (conflicts that seemed to be relegated to a low priority in earlier discussions) were given greater credence by several teachers when they talked about students' avoidance of science classes and careers.

Primary Responsibility of Science Teachers

The way people teach relies fundamentally on their vision of what is good teaching in a particular situation (Duffee and Aikenhead, 1992). Thus, teachers in science classrooms with Aboriginal students have an image of what a good teacher would do, an image that may provide us with a useful context for understanding the comments expressed during the interviews. Accordingly, in all three phases of our study (the quantitative, the qualitative, and interview phases) we asked teachers to express their ideas on the primary responsibility of a science teacher.

The quantitative responses are shown in Table Z2 (taken from Table E in Appendix 7). The most attractive image of teaching was expressed by item E12, empowering students to think for themselves. The same item in the qualitative instrument received somewhat different responses (see Table E12), responses replete with qualifications that try to balance the need for independent thinking with the need to rely on knowledgeable authorities.

Tables Z2 and E12 fit here. See Appendix 8.

Toward the end of each interview, teachers were asked to resolve the problem raised by the qualitative instrument, the problem of balance between thinking for oneself and relying on experts and authorities. Most teachers focused on expressing their personal goal as a science teacher.

Ted (527) and Alice (296) both stressed the goal of empowering students to think on their own, and both added that their goal could only be realized if they made science come alive for students (Alice, 313) and used lots of hands-on activities (Ted, 610).

Jack, Gary, and Betty talked briefly about how students should become independent critical thinkers, posing questions, seeking knowledge, and being "open-minded in accepting information" (Gary, 528).

Larry gave special attention to the need to have a knowledge base from which to think for oneself (514), and as a consequence, students needed the skills to learn enough to move on to the next level of education (447). Rose (324) emphasized making students' curiosity come alive so that students do not just accept ideas, but are empowered to question experts. Rather similar was Doug's call to "provide students with the tools to evaluate knowledge" (421) but added his goal of developing "a scientific way of thinking" in his students (423) even though it is only one way of thinking.

Joe's idea was to instill curiosity and get students to think on their own (251), and added that students have the potential to be curious but their Aboriginal culture takes things for granted (325).

Brent (769) saw his primary responsibility as empowering students to think and function independently in various different cultures, but for them to have the common sense to ask experts when appropriate. Brent's view seemed to sum up many of the other teachers' goals.

Another theme regarding a science teacher's primary responsibility was identified and underscored by several teachers: the importance of making connections between science content and the students' everyday lives. Betty (116), Alice (146), Rose (209), and Larry (503) described specific instances of a significant connections. According to many of our interviewees, science fairs and "Science Olympics" seem to have a major impact on students. Evidently, some Saskatchewan First

Nations and Métis students experience science lessons and activities at school that are meaningful and beneficial to them. Based on the teachers' information, science comes alive for these students. These successful instances of making connections between school science and students' culture might inspire and guide other teachers' initiatives in other schools.

A different type of connectedness was introduced by teachers when they lamented the fact that few Aboriginal students felt connected to nature (in spite of living in Northern communities) and too few felt connected to their own First Nations and Métis culture (Betty, 107; Brent, 79; Rose, 109). Such feelings of disconnectedness have preoccupied many First Nations and Métis educators in the past (Barman et al., 1989; Battiste and Barman, 1995; Deyhle and Swisher, 1997). The problem of disconnectedness to nature and to First Nations culture is certainly pervasively serious in the minds of several participants.

Summary

The beliefs of the science teachers varied considerably from topic to topic. Each teacher had a vision of teaching related to his or her ideology about schools, about student learning, about culture, about science, and about the connection between culture and science. This information strengthens our understanding of current science teaching and it may eventually lead to future improvements in curriculum and instruction for First Nations and Métis students. To explore our understanding of science teachers' beliefs further, the data presented above are analysed to tease out significant and useful ideas that may guide future improvements. We now turn to that analysis.

ANALYSIS

Our participants expressed varied, and sometimes incompatible, beliefs about science and about the connection between science and culture. The analysis of these beliefs will proceed at two levels. First we look at our results at a surface level, taking them at face value. We address the key question, "What is the nature of First Nations and Métis students' educational experience in the K-12 public system?" Secondly, we present a more in-depth analysis of our results, guided by previous research on collateral learning and cultural border crossing.

First Level Analysis

The beliefs of the teachers who participated in the SCN project seemed, on the surface, to be completely at odds with the views of the First Nations educators whose ideas were summarized in the "Literature Review" section of this report. The cultural conflicts between First Nations and scientific ways of knowing described by the First Nations authors were either (1) unknown to some teachers, (2) ignored by some others, or (3) rationalized into a non-problem by another group of teachers. This occurred when teachers discussed several topics (reported in the previous section): "Aboriginal Knowledge Inhibits Learning Science", "Consequences to Mastering Science", and "Science as a Foreign Culture". Our research results suggest that many of the Saskatchewan science teachers were not strongly aware of the differences (and underlying conflicts) between scientific and Aboriginal knowledge systems (similar to their United States counterparts; Allen, 1995; Gallagher, 1991; Nelson-Barber and Estrin, 1995). Two exceptions should be noted, however. Alice (70) did acknowledge the foreignness of science's reductionism, and Joe (375) did point out science's lack of respect for Mother Earth, as potential differences between the two ways of knowing. But neither teacher felt the problem was an obstacle for any of their students.

Teachers did not generally subscribe to the dilemma: how can students master and critique a Western scientific way of knowing without, in the process, sacrificing their own cultural ways of knowing? Only Joe (144) warned that students could lose something valuable from their own culture if science teachers did not watch out for the problem, while Alice (156-179) acknowledged that losing something valuable depended on the individual and community. She did not elaborate on the

influences that might account for individual and community differences. For the other participants, the dilemma remained largely unstated throughout the interviews. Perhaps this follows logically from a belief that science is academic not cultural. In any case, the dilemma did not seem to have significance to the practical daily events in the science classroom. Other issues and problems had much greater significance to teachers.

Most interviewees were articulate and persuasive in denying (or marginalizing) any cultural conflict between First Nations and scientific ways of knowing, until they were confronted with the fact that so few Aboriginal students entered science related fields, even among those who did go on to post-secondary education. The teachers' explanations for this fact spoke realistically to a variety of student inadequacies, for example, inadequacies in their self-confidence, language and math skills, academic orientation, and strength of family culture and support. But not one teacher broke through this wall of empirically verifiable excuses to see a more fundamental issue of cultural diversity or socioeconomic disparity, evidenced in the research literature (for example, Barman et al., 1986; Buckley, 1992; Deyhle and Swisher, 1997; Nelson-Barber and Estrin, 1995).

At the present time, therefore, our participants would probably not embrace the need to become culture brokers to help Aboriginal students negotiate cultural borders between their family life culture and school science culture. Instead, teachers' efforts are currently directed towards adding a measure of Aboriginal content to conventional science instruction, towards participating in school-wide programs that teach Aboriginal knowledge, or towards engaging students in science activities that make connections to students' everyday worlds. These approaches tend to force students to navigate transitions between home and school science on their own — a situation described by Phelan et al. (1991) and quoted earlier in the "Literature Review" section but worth repeating here:

> Many adolescents are left to navigate transitions without direct assistance from persons in any of their contexts, most notably the school. Further, young people's success in managing these transitions varies widely. Yet students' competence in moving between settings has tremendous implications for the quality of their lives and their chances of using the education system as a stepping stone to further education, productive work experiences, and a meaningful adult life. (p. 224)

We might anticipate that Betty's, Alice's, Rose's, and Larry's efforts at making connections between

school and everyday life would help students navigate between the two domains. But as found in the "Literature Review", Pomeroy (1994) distinguished between (1) bridging students' worldviews and the worldview of science (her agenda item number eight) and (2) exploring the content and features of both ways of knowing (her agenda item number nine). In the *bridging* type of connections, negotiating transitions between the two domains is largely implicit; while in the *exploring* type of connections, negotiating transitions is largely explicit. We do not have classroom observation data to conclude which type of connection Betty, Alice, Rose, and Larry generally used. Phelan et al.'s point is that students need *explicit* help to manage the transitions. In other words, border crossings between home culture and school science culture need to be explicit experiences. Alice hinted at this explicitness when she explained, "I always try and have two charts for the dictionary: the scientific term and what it means to us. They [the students] like things like that" (276-277). This approach is supported by Dukepoo (1993, p. 4): "Elements of cultural knowledge do not create barriers in the study of science; but rather can enhance, excite and stimulate scientific curiosity and inquiry. ... Teaching... can engender cultural appreciation, understanding, respect and acceptance". Student success depends on *how* a teacher approaches school science -- through cultural appreciation but seldom through note-taking of correct answers.

Some students may be dissuaded from science by the lack of explicit help in managing their cultural border crossing into school science. We must also consider other students who wish to play Fatima's rules (see Table 1) and get passing grades without the intellectual involvement demanded by cultural border crossing into school science. The teachers who were interviewed did not mention the game playing we refer to as Fatima's rules, except when two teachers referred disparagingly to their colleagues' note-giving textbook approach to teaching science. It was as if such game playing were absent from their own classrooms. The effect of an Aboriginal culture on students' current success in school science, and on students' desire to take future science courses, may be explained in part by their culture's lack of support for them to engage in superficial learning that has no attractive reward. While middle-class and upper middle-class non-Aboriginal students tend to be supported by their family culture when engaging in (or excelling at) Fatima's rules, traditional Aboriginal culture does not value that form of expedience (Ermine, 1995). The attempts by several of our participants to make connections between a student's everyday world and science can be seen

as attempts to avoid playing Fatima's rules. But by grade 7, many Aboriginal students may have, on the one hand, learned the Western educational system's convention of playing Fatima's rules as one way to succeed; but on the other hand, rejected that convention because it conflicted with a traditional Aboriginal cultural value. In Australia, Loughran and Derry (1997) investigated non-Aboriginal students reactions to a science teachers' concerted effort to teach for meaningful learning ("deep understanding") by making connections between the students' everyday world and science content. The researchers found a justification for Fatima's rules in the culture of public schools themselves.

> The need to develop a deep understanding of the subject may not have been viewed by them [the students] as being particularly important as progression through the schooling system could be achieved without it. In this case such a view appears to have been very well reinforced by Year 9. This is not to suggest that these students were poor learners, but rather that they had learnt how to learn sufficiently well to succeed in school without expending excessive time or effort. (p. 935)

Their teacher lamented, "No matter how well I think I teach a topic, the students only seem to learn what they need to pass the test, then, after the test, they forget it all anyway" (p. 925). Tobin and McRobbie (1997, p. 366) documented a teacher's complicity in Fatima's rules: "There was a close fit between the goals of Mr. Jacobs and those of the students and satisfaction with the emphasis on memorisation of facts and procedures to obtain the correct answers needed for success on tests and examinations." When playing Fatima's rules, students (and some teachers) go through motions to make it appear as if meaningful learning has occurred, but at best rote memorization of key terms and processes is only achieved temporarily.

This means that even if teachers reacted to Phelan et al.'s (1991) observation (quoted above) by consciously and explicitly trying to help students cross a cultural border into school science, if students perceived the school culture as embracing Fatima's rules, students may reject the teacher's well meant attempt to create smoother border crossings for them. Thus, changing a science classroom into a culturally sensitive environment may be insufficient without the school-wide support for cross-cultural instruction that engenders cultural appreciation, understanding, respect, and acceptance.

What is the nature of First Nations and Métis students' educational experience in the K-12 public system? In addition to unconsciously abandoning students to negotiate cultural borders into

science classrooms mostly on their own (specific efforts by a few teachers documented in the "Findings" section — Rose, Alice, Betty, Joe — not withstanding), the results of our research suggest that while most teachers acknowledged the validity of Aboriginal knowledge, few stated that they were able to support Aboriginal students sufficiently by incorporating that content into their science classes. All the teachers interviewed felt badly at the lack of resources that could help them support Aboriginal students adequately. This lack of resources was cited by most of the participants as the main reason that only a token amount of Aboriginal knowledge was introduced into their science programs. Moreover, given the comments our teachers made about what they see happening in many other classrooms (note-taking and textbook content memorizing), the teachers who did not participate in this research project are *not* likely to be more supportive of Aboriginal students in ways described above by Phelan et al. (1991).

The teachers in our study were unanimous in rejecting the idea that their science classrooms purposefully assimilated Aboriginal students into a Western worldview. The reason for this rejection may be quite simple: no assimilation can take place because science is not really cultural. In other words, the teachers did not envisage Western science (the conventional focus of their science classrooms) as a cultural expression of a Euro-American worldview (although the idea was recognizable to them in an intellectual way). Because students can only be assimilated into fields that are cultural in nature, the issue of assimilation in their science classrooms may not have existed in their minds. This means that some teachers may have unintentionally worked towards assimilating some students into a Western way of thinking. One way to avoid unintentional assimilation is to identify cultural border crossing into school science, and thereby make it explicit to both teachers and students, treating Western science as one way of knowing, but not *the* way of knowing (MacIvor, (1995).

In summary, given the empirical fact that teachers affect student outcomes more than the science curriculum (Welch, 1969), teachers who want Aboriginal students to succeed in science must not be undermined by (1) a lack of instructional resources, (2) an absence of cross-cultural approaches to instruction, and (3) a pervasive school culture that inadvertently promotes Fatima's rules. In addition, the students whose families support a First Nations and Métis culture will prosper from a science curriculum framed by an Aboriginal worldview, while students who are disconnected from

their cultural roots may not find such a curriculum to be relevant. (It seems that many Saskatchewan classrooms have both types of students.) This latter group challenges science educators to engage in school-wide efforts to re-establish traditional values and knowledge so students will feel more connected to nature and to their First Nations and Métis cultures. Traditional values and knowledge may likely be controversial, however, in communities where opposition to First Nations spirituality is strong.

Second Level Analysis

Upon deeper analysis, a slightly different, more complex picture emerges. Some teachers seemed to have gone beyond a simple recognition of cultural conflict between First Nations and scientific ways of knowing to the point where these teachers achieved some kind of resolution to that conflict. Their resolution may have obscured the original cultural conflict. Thus, the reflections of teachers who at one time experienced cultural conflict can be interpreted as *resolutions* to the original underlying cultural conflict, rather than as an articulation of the original underlying conflict.

Collateral Learning

If teachers understood how different people perceive and resolve cultural conflict, then perhaps those teachers could be effective culture brokers by helping students perceive and resolve cultural conflicts that arise in science classrooms. Some teachers (Larry and Brent) resolved cultural conflicts between First Nations and scientific ways of knowing by allocating each to a separate domain (different "pockets"), while other teachers (Betty, Alice, and Joe) strived to "mesh" the two into a meaningful self-consistent worldview. We should expect among students the same variation in ways of resolving cultural conflicts. For example, Larry might not be as good a culture broker if he were not aware of some students' need to mesh the two domains of knowledge, rather than treat them as independent but parallel domains as he does. Similarly, Betty might "fail" her students who feel comfortable only when engaged with independent but parallel domains of knowledge.

The process of resolving a conflict between two ways of knowing was described by Jegede (1995, 1996, 1997) in terms of various types of collateral learning (parallel, simultaneous, dependent, and secured; described earlier in the "Literature Review" section). Several of our interviewees

demonstrated different types of collateral learning.

Joe introduced the need for collateral learning when he stated:

> Myself, I do have some beliefs that were told to me a long time ago and I keep those, and then I accept certain scientific facts but I don't let my beliefs get in the way of that; as long as I differentiate. (lines 154-157)

Joe hinted at the way he deals with conflicting explanations. He sees scientists and Elders at opposite extremes when it comes to making sense of, for instance, a tornado (lines 372-374). This approach suggests parallel collateral learning, though we do not have sufficient information to tell. (Alternatively, Joe may have developed a conscious conflict resolution strategy, and if so, his learning would be secured collateral learning with a multiple-world orientation — as opposed to a holistic orientation.)

Larry was more explicit about parallel collateral learning when he advocated that students need to "suspend belief" (line 57) for a period of time to resolve a conflict between scientific evolution and the biblical account of the origin of humans. In the context of discussing whether or not Aboriginal students will likely lose something valuable in their own culture if they master science, Larry introduced his "pockets" metaphor:

> I think if you have a strong family and strong cultural beliefs, I don't think you'll lose anything. I really don't. I think that you can separate it. You can put this in that pocket and this in that [other] pocket. (lines 286-289)

He warranted his claim by referring to his experiences in Africa. A similar argument was suggested by Brent when he explained that Aboriginal students can sometimes double their horizons by acquiring scientific knowledge in addition to their First Nations knowledge (line 251), with the result that they will function well in both societies — Aboriginal and Western (line 770).

Alice, on the other hand, argued strongly that you can not separate science content and students' culture (lines 256-268), otherwise science is not connected to students' experiences and they will not learn science. She appears to advocate secured collateral learning (within a holistic orientation towards knowledge) in her science program. Betty, too, advocated holistic secured collateral learning when she described the difficulty Aboriginal students experienced when they separated science from First Nations knowledge.

They see them as two separate things instead of one unified thing, or things that are related somehow. ... I'm learning how to mesh the two. (lines 211-219)

Later in the interview when talking about learning the foreign language of science, Betty explained:

And if they don't happen to be very knowledgeable about their own culture, then that gives them an opportunity to approach somebody within their culture like an elder and ask some questions. (lines 327-329)

This event signifies spontaneous collateral learning, where science content motivates students to learn First Nations knowledge along with, but initially separate from, scientific knowledge, or visa versa.

Our results show that when people perceive conflict between science and First Nations knowledge, they have diverse ways of dealing with their perceived conflict. These ways can be understood by different kinds of collateral learning. Therefore, teachers' views about the connection between Western science and students' Aboriginal culture will vary according to the teachers' biases towards, or comfort with, parallel, dependent, or secured collateral learning. As a consequence, we should anticipate a match or mismatch between students and teachers in terms of the type of collateral learning they are comfortable with in the context of a particular science lesson. The quality of learning science will vary accordingly. If teachers are aware of their own preferred type of collateral learning, and are aware of the alternative types preferred by some of their students, then teachers have specific self-guidance to improve on their instruction of students who perceive a conflict. This awareness will improve the culture-broker role of science teachers.

A Cultural Perspective on Border Crossing

A different influence over the quality of learning can be identified in the results of our study. While each teacher described individual differences in students by alluding to various characteristics (for example, self-confidence, strength of family, degree of critical-thinking ability, or willingness to express one's reflections on an activity), Betty and Alice also described student differences in terms of how naturally students appeared to learn science. Betty talked about students who seemed to understand what was taught. "Just bang, they had it and that was the way it was" (lines 228-229). She also described another group:

Then there were other people like me who always wanted to know why, and I had a terrible

time understanding it. So therefore, even when I got the formulas and understood the basic idea behind the way they were teaching me, it couldn't dominate my thinking because I never really fully understood it. (Betty, lines 229-233)

Somewhat different from Betty's two categories (those who got science and those who had to work to get it), Alice identified two groups of students: those who like the science program they are getting and those who "just take it as an information class. They will try to learn as much information as they can" (lines 180-182). This information seeking was associated with getting marks to pass the course. Alice had less respect for information seeking than for a deep understanding of science. The categories of students suggested by Betty and Alice reflect varying degrees of ease with which students cross into the culture of science. In other words, the categories describe students' success in navigating the transition between home and school science. Phelan et al. (1991) systematically investigated the ease with which students negotiated the transition between home and school science, and Costa's (1995) research extended this work by identifying categories of science students based on how smoothly they negotiated their transitions. (See "Literature Review" and the summary in Table 1.) It is evident that Betty and Alice were mindful of students' ease in negotiating cultural borders, and both teachers seem to use a simple version of this idea when reflecting on their own teaching. We can only speculate how much more effective their reflections might have been if they had incorporated Costa's categories into their thinking. (See Aikenhead, 1997, for a short discussion on this point.) Using Costa's categories to reflect on one's students and one's teaching will likely increase teachers' sensitivity and appreciation of individual differences among their students.

At the same time, Betty has inadvertently created the need to fine-tune the category system that emerged from Costa's (1995) anthropological research. Betty's description of her struggles in school science (quoted just above) suggest that she negotiated *hazardous* transitions into school science, not by playing Fatima's rules (Larson, 1995) like disinterested students tend to do, but rather by acquiring a degree of understanding motivated by her curiosity or quest to learn more about the world. Her understanding of science was different from Costa's Potential Scientists whose worldviews coincide with a Western science worldview, whose transitions into school science are smooth, and who achieve a deep understanding of the subject. Betty's desire to understand science, motivated by her own interest in the subject, sets her apart from Costa's Other Smart Kids who do

not see science as relevant to their lives (other than for acquiring a high grade and course credit needed for higher education), but who are able to *manage* the transition into academic school science. Betty certainly does not belong to Costa's "I Don't Know" Students whose transitions into school science are hazardous because of a discrepancy between school culture in general and their own home culture, and who invariably play Fatima's rules to save face and do will enough at school. Certainly Betty does not fit the description of Costa's Outsiders or her Inside Outsiders.

For Betty and other students like her, we need to establish a category for people who display all of the following criteria: (1) they tend to experience hazardous border crossings into school science; (2) their personal worldview or home culture does not exactly mimic the worldview of Western science or the culture of schools; but (3) they are predisposed to learning Western science because of their personal curiosity about nature or their pervasive desire to learn more about the world in general; and hence, (4) they do not achieve a deep understanding of science but a modest yet effective understanding of science. A modest yet effective understanding of science is a world apart from the memorization and superficial learning that results from playing Fatima's rules. A new category of science students is proposed: "I Want to Know" Students. This category recognizes students (Aboriginal or non-Aboriginal) whose desire to understand Western science is made difficult, but not at all impossible, by the diverse worlds of their home culture and the culture of Western science conveyed in their science classroom. Our proposed modification to Table 2 is depicted in Table 3 (Appendix 1).

Table 3 fits here. See Appendix 1.

Costa's categories have direct implications for science curriculum (Aikenhead, 1996, 1997) as well as for improving instruction. Imagine the differences in the reflections of the interviewees had they been given the opportunity to think differently about their students, that is, to reflect on students crossing cultural borders into their science classrooms and experiencing different kinds of transitions (smooth, managed, hazardous but wanting to know, hazardous but wanting to look good, and impossible). When we perceive students differently, our planning and instruction can change

accordingly. "Crucial to academic achievement for many underserved students ... [is] the teacher's ability to fashion a curriculum that is more personal and more directly linked to students' cultural experiences" (Nelson-Barber and Estrin, 1995, p. 5). Our interview data offered instances of successful planning and instruction, but the instances were often described as isolated events, far more isolated than is needed for a sustained effort to improve science teaching for First Nations and Métis students.

Why do Aboriginal students avoid science in high school and university? About a half of our participants initially said they had no idea. They could not confidently make sense of the problem, let along resolve it. These teachers need a resolution to the problem before they can effectively encourage students to continue in science and mathematics — one gateway to cultural capital and economic power in Euro-American society (Davidson and Kramer, 1997; Nelson-Barber and Estrin, 1995). A promising resolution to the problem is to provide students with curricula and instruction that make students feel comfortable border crossing more smoothly between their own culture and the culture of school science (Aikenhead, 1997).

The interview data were replete with constraints that compromised successful science instruction. These constraints will not be diminished by adopting a cultural perspective on student learning (border crossing into the culture of school science with varying degrees of ease), but such a perspective could give us creatively new ways to circumvent some of those constraints.

RECOMMENDATIONS

> *Teaching Native students [is] a search for the ideal balance between maintaining the Native way of life and achieving economic and political independence* (Leavitt, 1995, p. 126).

Recommendations are always made within a context, whether specified or not. We believe it is important to clarify the various contexts within which our recommendations fit. Some contexts come directly from our participant teachers' experiences, while others were identified by the systematic research results reported in the literature and by the interaction (or lack of interaction) between teachers' responses and this literature.

Research on implementing new ideas for science curricula and instruction have consistently shown that student achievement depends first and foremost on the individual student, and secondly, on who the teacher is (Welch, 1969). Moreover, the vision and abilities of teachers make a bigger difference to student achievement than the curriculum or specific instructional strategies used. Student success seems to spark when the curriculum and instruction *support* teachers who nurture students with cultural backgrounds different from the teacher's or from the culture of the school (Trentacosta, 1997). Success depends on a synergetic interaction of students, teachers, methods of instruction, curriculum, and school culture. Drawing upon Ladson-Billings's *The Dreamkeepers: Successful Teachers of African American Children*, Walker and McCoy (1997) concluded, "*The way we teach* has the greatest impact on how students perceive *what we teach*" (p. 136, emphasis in the original).

School science happens within school and community cultures and only rarely can teachers and students work outside those pervasive cultures. Therefore, the support by school and community cultures for Aboriginal students studying science forms a crucial part of the context of our recommendations. For instance, the success of Joe Duquette School in Saskatoon has been attributed, in part, to the nurturing environment achieved by the school culture (Aikenhead and Binsfeld, 1996; Haig-Brown et al. 1997).

As a consequence, we recognize that our recommendations to help teachers become more effective science teachers for First Nations and Métis students are hollow without the support of their

community and school. Many of our recommendations involve a shared responsibility among teachers, administrators, local educational authorities, Saskatchewan Education, and the universities. The recommendations are organized into clusters, and they are very much interrelated. The list roughly goes from the broadly general to the locally specific.

Recommendation 1.

Schools should validate and teach First Nations knowledge (that is, to enculturate First Nations and Métis students into their mother culture). This is particularly appropriate for Aboriginal students who presently seem disconnected from their mother culture. Our research results showed that enculturation is occurring in some schools already. Science courses by themselves, however, cannot enculturate Aboriginal students into their mother culture.

Recommendation 2.

Knowledge of nature learned in school science should combine both Aboriginal and Western science knowledge systems. This view was expressed by our participants when they spoke of making connections between school science and the students' everyday lives, as outlined by MacIvor's (1995) goals for First Nations science education, and as described by Pomeroy's (1994) 9th agenda item.

2.1 Students' Aboriginal culture/language/knowledge must be seen by students and treated as an asset to learning Western science, and not as a liability. This will help teachers and students build bridges to the dominant Euro-Canadian culture (Estrin, 1993). Science classes should legitimate what students already know from their First Nations and Métis culture. If students do not know much, they should find out from resources in their community. Betty pointed out two reasons for this strategy: to help students grow personally, and to get students to teach the rest of the class in a way appropriate to the culture.

2.2 A First Nations worldview should frame a science curriculum, within which appropriate Western science knowledge, skills, and values are studied in a culturally sensitive way. The current Saskatchewan science curriculum, with its STSE (science-technology-society-environment) emphasis, implicitly encourages this approach, as several teachers mentioned.

2.3 Culturally sensitive school science will explicitly acknowledge "cultural border crossing" as

a way that students negotiate the transition between their home cultures and the culture of school science.

2.4 Culturally responsive science instruction requires teachers to take up a culture-broker role: to help students feel at ease (to be flexible and playful) in the culture of Western science, and to help students resolve conflicts that may arise between their home culture and the culture of Western science found in the classroom. Leavitt (1995, p. 126) concluded that we must recognize four aspects of culture. In the context of science teaching, these aspects are: the *material* cultures of the community and of science, the *social* cultures of the community and of science, their two *cognitive* cultures (their worldviews, value systems, and spiritual understanding), as well as their two *linguistic* cultures.

Instances of culturally sensitive curriculum and culturally responsive instruction were evident intermittently on a small scale in our research data. Thus, these recommendations speak to expanding the frequency of those instances so they become the conventional practice, rather than the celebrated exceptions. Table 4 shows one alternative to current conventional science teaching. It is a revision of Table 1 and specifically avoids cultural assimilation of Aboriginal students into Western ways of thinking, an avoidance embraced by all the interviewees in our study.

Table 4 fits here. See Appendix 1.

Recommendation 3.

Identify a group of teachers who are already fulfilling some of the principal roles of a culture broker, and then form a working network among these teachers and with other educators who could facilitate their collaborative work. This group would collaboratively carry out research and development (R&D) individually in their classrooms and together as a network. Their mandate would include the following general points:

3.1 Identify classroom environments and procedures, as well as collate available teaching resources of all types (including protocols for approaching elders), that enhance a science teacher's role as a culture broker for First Nations and Métis students. (Two ideas may be to

reflect on the collateral learning — learning in the context of potentially conflicting knowledge systems — to be achieved by a diverse group of students who are identified by their degree of ease in cultural border crossing into the culture of school science. The literature described degrees of ease in terms of smooth, managed, hazardous, and impossible; Costa, 1995.)

3.2 Develop: (a) a culturally sensitive science curriculum; (b) an array of culturally responsive instruction and assessment/evaluation practices; and (c) specific lessons, units, and modules. The curriculum, practices, and classroom materials should all nurture the classroom environments and procedures identified in point 3.1. Educational experiences should connect students to nature and to their everyday culture, while at the same time, these experiences should provide students with an pragmatic understanding of the culture of Western science (depicted in Table 4). Pragmatic understanding relates to economic and political independence. Hands-on and "minds-on" experiences require continual support from the school (a room with running water, for instance). "Let's face it, when sciencing things aren't made available to them [teachers], it's much easier to open your textbook and talk about it and write questions and get it over with" (Betty, 145-147). Success in the past has generally come from science/technology projects (science fairs and science Olympics, for example) as well as from field trips into the local environment.

3.3 When developing a culturally sensitive science curriculum, the network of educators should address: (a) the issue of Fatima's rules (rules about how to pass science courses without really understanding the content — as Betty referred to it, "students go with the information and memorize as much as they can without actually doing any new learning" [186-187]); and (b) four types of student outcomes: mental, emotional, physical, and spiritual. The mental (cognitive) outcomes should be addressed in terms of various types of learning, including collateral learning (parallel, simultaneous, dependent, and secured).

3.4 Given the almost unique culture of each school jurisdiction, curriculum materials should be stored on disk so that a local science committee (consisting of a teacher, selected students, and community resource people) can oversee its modification to fit the unique cultural contours of the community. Materials are rarely effective when transferred from one jurisdiction to

another, without being edited and adapted by those who are likely to use the materials. Elders need to validate certain content and to suggest ways to teach students the content, other than through the personal appearance of an elder. This process of adapting materials to a specific jurisdiction will identify local resources and protocols, and will define an appropriate First Nations framework and content for the science curriculum.

3.5 Investigate the culturally influenced notions of "good science teaching" found in different communities.

3.6 Develop outlines for in-service and pre-service programs that (a) create a perceived need for a science teacher to become a culture broker, and (b) provide support for teachers as they identify their own strengths as culture brokers and take on additional practices to become more effective culture brokers.

Recommendations 4.

Saskatchewan Education, in conjunction with other interested agencies and organizations, should fund the original network of educators, and should plan to expand the network once the initial R&D is completed. The tasks ahead are time consuming and challenging. Teachers cannot begin to conduct their R&D work without: (a) an initial week-long orientation workshop in late August; (b) a half-time teaching load reduction for a complete year; (c) an internet communication system among themselves, and (d) an appropriate load reduction to assist with the subsequent year(s) with the expanded network.

Recommendation 5.

4.1 *Children in elementary schools (grades 1-6) should experience enough hands-on materials to develop routines of proper behavior around materials in classrooms.* Thus, when students engage in science activities in middle years, their appropriate behavior around materials should be an asset to learning. Where this appropriate behavior is already being achieved, the network should identify the salient characteristics of such a school.

4.2 *Children in elementary school science should learn that their hands-on experiences with materials and with nature are genuine instances of being a scientist themselves.* Betty put it this way: "calling them [the children] 'scientists' from the time they are in grade one making their little mud pie type thing and learning from it... " (172-173). This should help diminish the Einstein icon of a scientist held by so many students; an icon that tends to inhibit students' meaningful participation in science. "Middle years is a tough time to start introducing those ideas. You have to start younger than that. Carrying it through. They're scientists" (Betty, 176-178).

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APPENDIX 1

Tables 1 to 4

Table 1. The Conventional School Science Curriculum

GOAL
Cultural transmission of canonical science content (the knowledge, values, and skills used by the scientific community).
PROCESSES
Enculturation: a student learns the canonical content of science, which is in harmony with her/his indigenous view of the world, by incorporating that content into her/his personal view of the world. Scientific thinking enhances a person's everyday thinking.
Assimilation: a student learns the canonical content of science, which is at odds with her/his indigenous views of the world, by replacing or marginalizing those indigenous views. Scientific thinking dominates a person's everyday thinking.
Fatima's rules: school "games" (played by a student and teacher) allow students to get passing or high grades without understanding the course content in a meaningful way, the way the community assumes students understand it. Scientific thinking does not exist for a student and hence it does not connect with a student's everyday thinking.

Table 2. An Overview of a Cultural Approach to Science Education

Border Crossings	Student Categories	Role of Teacher	Collateral Learning
smooth	Potential Scientists	coaching apprentices	none, parallel, or secured
managed	Other Smart Kids	travel agent culture broker	parallel or secured
hazardous	"I Don't Know" Students	tour guide culture broker	dependent
impossible	Outsiders	tour guide culture broker	little or no learning (parallel or dependent, it at all)

Table 3. A Revised Overview of a Cultural Approach to Science Education

Border Crossings	Student Categories	Role of Teacher	Collateral Learning
smooth	Potential Scientists	coaching apprentices	none, parallel, or secured
managed	Other Smart Kids	travel agent culture broker	parallel or secured
hazardous	"I Want to Know" Students	tour guide culture broker	parallel, dependent, or secured
hazardous	"I Don't Know" Students	tour guide culture broker	dependent
impossible	Outsiders	tour guide culture broker	little or no learning (parallel or dependent, it at all)

Table 4. A Cross-Cultural Perspective on the School Science Curriculum for Aboriginal Students.

GOAL

Transmission of Aboriginal culture along with a cross-cultural transmission of science and technology.

PROCESSES

Enculturation: a student learns Aboriginal knowledge, values, and skills in harmony with his/her indigenous view of the world, by incorporating them into a personal view of the world. Aboriginal thinking enhances a person's everyday thinking.

Autonomous acculturation: a student borrows or adapts (incorporates) some content from Western science and technology because the content appears useful to him/her, thereby replacing some former indigenous views. Everyday thinking is an integrated combination of commonsense thinking and some science/technology thinking.

"Anthropological" instruction: a student learns the content of subculture science similar to an anthropologist learning the ways of a foreign culture. The subculture of science is a repository to be raided, but its thinking does not connect with a person's everyday thinking, yet a person can do either type of thinking, depending on the context.

APPENDIX 2

Quantitative and Qualitative SCN Instruments Used in the Study

Science and Culture Nexus Survey

(Saskatchewan Version -- Quant.)

Dear Colleague,

This is a survey designed to gather some information on people's perceptions about the nexus (connections) between science and culture. The aim is to document the current views of science educators about culture and Western science, their interactions, and possible effects on student learning and your professional practice. Of specific interest is the connection between First Nations and Métis cultures and the culture of Western science found in the science curriculum. You are invited to be part of this project by completing this questionnaire made up of two sections. Section A seeks biographical information while Section B (five groups of questions to be answered from two different perspectives) contains the items related to the main focus of the survey.

To complete Section B of the questionnaire please **tick** ✓ the box which best represents your situation. There are two different perspectives to consider: what you perceive to be the views of your colleagues, and what your personal view is. Please do not write your name on the questionnaire. Your responses are confidential and anonymous, and therefore they form part of the aggregated results on all opinions gathered.

Thank you very much.

Sincerely,

Glen Aikenhead
Curriculum Studies
28 Campus Drive
Saskatoon, SK
S7N 0X1
(306) 966-7563

and

Bente Huntley
SUNTEP Prince Albert
48 - 12th Street East
Prince Albert, SK
S6V 1B2
(306) 764-1797

SECTION A:

Biographical Data

1 **Gender:** ☐ Male ☐ Female

2 **Nation/Tribal Aboriginal background:** _____, Fill in either

3 **Ethnic/racial non-Aboriginal background:**_____, 2 or 3, not both

4 **Nationality:**_____

5 **Country of birth:**_____

6 **How long have you lived in your community?:**

☐ Less than 5 years ☐ 5-10 years ☐ 11-15 years ☐ 16-20 years ☐ More than 20 years

7 **Main language spoken at work:**_____

8 **Main language spoken at home:**_____

9 **Principal occupation:**

☐ Science Teacher ☐ Science Teacher Educator ☐ Science Professor/Lecturer

☐ Curriculum Developer ☐ Policy Maker/Administrator ☐ Other (Please specify)_____

10 **Years of experience in your current occupation:**

☐ Less than 5 years ☐ 5-10 years ☐ 11-15 years ☐ 16-20 years ☐ More than 20 years

11 **Highest educational qualification:**

☐ High School/Secondary Certificate ☐ Diploma ☐ Bachelor degree ☐ Masters in _____

☐ Ph.D. in _____ ☐ Other (Please specify)_____

12 **Subject areas of major educational preparation: (check more than 1 if applicable):**

☐ Mathematics ☐ Chemistry ☐ Physics

☐ Biology ☐ Integrated/General Science ☐ Technology/Engineering

☐ Geography ☐ Other (Please specify) _____

13 **Which level of science does your work mostly involve?:**

☐ Primary School (grades 1-6) ☐ Secondary ☐ Primary & Secondary ☐ Teacher Education

☐ University/College Science ☐ Technical Institution ☐ Industry ☐ Other (Please specify) _____

14 **Please identify the cultural identify of the everyday common (indigenous) knowledge in your community:**

_____

15 **Please list areas of major teaching duties:**

_____

SECTION B: SASKATCHEWAN VERSION

Instructions: This section seeks your comments on the views held by most of your colleagues you work with or interact with at work or through professional development. Please tick the box which best represents what you perceive to be the views of your colleagues, and your personal view. You may wish to regard 'everyday common knowledge' as 'Aboriginal, indigenous knowledge' in this questionnaire, or whatever you answered in question 14, Section A.

Items	Views held by most of my colleagues					My personal view				
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree
A. Science										
1. Science is a body of verified knowledge, such as principles, laws, and theories, which describe and explain the world around us.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. Science is exploring the unknown and discovering new things about our world and universe and how they work.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3. Science is carrying out experiments to solve problems of interest about the world around us.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4. Science is inventing or designing things (for example, artificial hearts, computers, space vehicles).	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5. Science is finding and using knowledge to make this world a better place to live in (for example, curing diseases, solving pollution, and improving agriculture).	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6. Science is an organization of people (called scientists) who have ideas and techniques for discovering new knowledge.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
7. Science is a rational perceiving of reality.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
8. Science is the basis of most technological advances.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
9. Technology does not need to have a scientific basis, technology can advance on its own know-how.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
10. Science generally represents a male perspective on the world.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
11. Every occurrence in nature has a scientific explanation.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
12. Science represents a wholistic/comprehensive perspective about natural phenomena.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
13. Science provides the most plausible explanations of natural phenomena.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Items	Views held by most of my colleagues					My personal view				
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree
B. Science and Culture										
1. Science teachers attempt to socialize/or enculturate students into a community of scientific practitioners.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. It is easy to incorporate science into one's personal views of nature.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3. Scientific knowledge once acquired often dominates one's way of thinking.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4. Science alienates people from their traditional culture.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5. A person can integrate science with Aboriginal spirituality.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6. My community appears to be turning against science.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
7. Science is often seen as a subculture of Western culture.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
8. Every occurrence in nature has a non-scientific/ culture-based explanation.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
9. Many of nature's occurrences are mysterious.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
10. Science can teach how to survive in everyday life situations.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
11. When science is practised in a community, it reflects a community's values and beliefs.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
12. Science will progress the same way irrespective of the culture of the scientists involved because science is universal.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
13. Western beliefs, values, and conventions are an implicit aspect of science.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
14. Science can help the progress of non-Western people if they would only assimilate science into their way of thinking.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
15. Science can empower people who belong to a traditional culture, as long as those people learn science without taking on the Western beliefs that are a part of science.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
16. Science has helped some nations colonize other nations of a different culture.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Items	Views held by most of my colleagues					My personal view				
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree
C. Science and Everyday Common (Indigenous) Knowledge										
1. Scientific ideas and everyday common knowledge within my immediate community have similarities.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. Scientific knowledge stands out as being separate from the common knowledge of my community.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3. Science and everyday occurrences are so different, it is almost like they belong to different worlds.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4. Scientists/science educators often use scientific ideas to support ideas found in everyday common knowledge.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5. Scientists/science educators often use ideas from everyday common knowledge to support scientific ideas.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6. Students' belief in everyday common knowledge inhibits their learning science.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
7. Evidence arrived at through scientific means is not always regarded as sensible to everyday common knowledge.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
8. Scientific explanations and everyday common knowledge of natural phenomena should always be treated differently.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
9. Scientific explanations and everyday common knowledge of natural phenomena should always be treated as one.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
10. Scientific explanations of natural phenomena are relevant to everyday societal issues.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Items	Views held by most of my colleagues					My personal view				
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree
D. Culture										
1. Culture is the lifestyle of a people.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. Everything that is not nature is culture.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3. Culture is a system of meaning that a people create for themselves.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4. Culture is the totality of a people's identity.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5. The expression of culture is influenced most by peers and family members.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6. The culture of a people is permanent because it is transmitted from one generation to another.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
7. Cultural knowledge is embodied most of all in one's language.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
8. Cultural hybrid results from inter-marriages between people of different cultures.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
9. Nature (heredity), rather than nurture (environment), influences cultural change.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
10. Nurture, rather than nature, influences cultural change.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
11. Both nurture and nature interact and influence cultural change.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
12. Learning another culture's way of thinking about natural phenomena can empower people by providing them with a new way of thinking.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
13. Cultural assimilation can oppress people by marginalizing or dominating their ideas.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Items	Views held by most of my colleagues					My personal view				
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree
E. Teaching and Learning Science										
My responses to items 1 - 14 below will relate to science education at the:										
☐ primary level grades 1-6 ☐ secondary level grades 7-12 ☐ tertiary level										
1. The teaching of science centres mainly upon the transmission of verified knowledge.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. The teaching of science centres mainly upon students making personal meaning out of scientific knowledge.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3. Most of the current science teaching methods encourage mere acquisition of unrelated information.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4. Science concepts taught in school reflect the dominant culture in my immediate community.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5. Scientific ideas are compatible with ideas within an Aboriginal community.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6. Science teaches the rejection of ideas held by an Aboriginal community.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
7. School science imposes a foreign set of cultural values on an Aboriginal student.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
8. Science and Aboriginal knowledge can both be taught in a science classroom..	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
9. Science and Aboriginal knowledge should both be taught in a science classroom..	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
10. The science concepts taught in school science have no meaningful use beyond passing examinations.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
11. The primary responsibility of a science teacher is to prepare students for postsecondary studies.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
12. The primary responsibility of a science teacher is to empower students to think for themselves, thereby emancipating students from a dependency on experts and other authority.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
13. The primary responsibility of a science teacher is to respond to the particular legitimate needs of students, whatever those needs are.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
14. If Aboriginal students master science, they will likely lose something valuable of their own culture.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
15. For many students, learning science is like going into a foreign culture.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Science and Culture Nexus Survey

(Saskatchewan Version -- Qual.)

Dear Colleague,

This is a survey designed to gather some information on people's perceptions about the connections (nexus) between science and culture. The aim is to document the current views of science educators about culture and Western science, their interactions, and possible effects on student learning and your professional practice. Of specific interest is the connection between Aboriginal cultures and the culture of Western science found in the science curriculum. You are invited to be part of this project by completing this questionnaire made up of two sections. Section A seeks biographical information while Section B (five groups of questions to be answered from two different perspectives) contains the items related to the main focus of the survey.

(i) Please **tick** √ the box which best represents your situation: what you perceive to be the views of your colleagues and, what your personal view is.

(ii) In the space provided in each section, write a justification for your choice of response, i.e., what reasons prompted the answer you have ticked. Use the back of the sheet if necessary.

Please do not write your name on the questionnaire. Your responses are confidential and anonymous. They form part of the aggregated results on all opinions gathered.

Thank you very much.

Sincerely,

Glen Aikenhead
Curriculum Studies
28 Campus Drive
Saskatoon, SK
S7N 0X1
(306) 966-7563

and

Bente Huntley
SUNTEP Prince Albert
48 - 12th Street East
Prince Albert, SK
S6V 1B2
(306) 764-1797

SECTION A:

Biographical Data

1 **Gender:** ◻ Male ◻ Female

2 **Nation/Tribal Aboriginal background:** _____, Fill in either

3 **Ethnic/racial non-Aboriginal background:** _____, 2 or 3, not both

4 **Nationality:** _____

5 **Country of birth:** _____

6 **How long have you lived in your community?:**

◻ Less than 5 years ◻ 5-10 years ◻ 11-15 years ◻ 16-20 years ◻ More than 20 years

7 **Main language spoken at work:** _____

8 **Main language spoken at home:** _____

9 **Principal occupation:**

◻ Science Teacher ◻ Science Teacher Educator ◻ Science Professor/Lecturer

◻ Curriculum Developer ◻ Policy Maker/Administrator ◻ Other (Please specify) _____

10 **Years of experience in your current occupation:**

◻ Less than 5 years ◻ 5-10 years ◻ 11-15 years ◻ 16-20 years ◻ More than 20 years

11 **Highest educational qualification:**

◻ High School/Secondary Certificate ◻ Diploma ◻ Bachelor degree ◻ Masters in _____

◻ Ph.D. in _____ ◻ Other (Please specify) _____

12 **Subject areas of major educational preparation: (check more than 1 if applicable):**

◻ Mathematics ◻ Chemistry ◻ Physics

◻ Biology ◻ Integrated/General Science ◻ Technology/Engineering

◻ Geography ◻ Other (Please specify) _____

13 **Which level of science does your work mostly involve?:**

◻ Primary School (grades 1-6) ◻ Secondary ◻ Primary & Secondary ◻ Teacher Education

◻ University/College Science ◻ Technical Institution ◻ Industry ◻ Other (Please specify) _____

14 **Please identify the cultural identity of the everyday common (indigenous) knowledge in your community:**

_____

15 **Please list areas of major teaching duties:**

_____

SECTION B: SASKATCHEWAN VERSION

Instructions: This section seeks your comments on the views held by most of your colleagues you work with or interact with at work o through professional development. Please tick the box which best represents what you perceive to be the views of your colleagues, and your personal view. You may wish to regard 'everyday common knowledge' as 'Aboriginal, indigenous knowledge' in this questionnaire, or whatever you answered in question 14, Section A.

Items	Views held by most of my colleagues					My personal view				
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree
A. Science										
1. Science is finding and using knowledge to make this world a better place to live in (for example, curing diseases, solving pollution, and improving agriculture).	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. Science represents a holistic/comprehensive perspective about natural phenomena.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Please provide reasons for your responses in the space below:

Items	Views held by most of my colleagues					My personal view				
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree
B. Science and Culture										
1. Science can empower people who belong to a traditional culture, as long as those people learn science without taking on the Western beliefs that are a part of science.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. Science alienates people for their traditional culture.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Please provide reasons for your responses in the space below:

Items	Views held by most of my colleagues					My personal view				
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree
C. Science and Everyday Common (Indigenous) Knowledge										
1. Scientific knowledge stands out as being separate from the common knowledge of my community.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. Scientific explanations and everyday common knowledge of natural phenomena should always be treated as one.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Please provide reasons for your responses in the space below:

Items	Views held by most of my colleagues					My personal view				
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree
D. Culture										
1. Learning another culture's way of thinking about natural phenomena can empower people by providing them with a new way of thinking.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. Cultural assimilation can oppress people by marginalizing or dominating their ideas.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Please provide reasons for your responses in the space below:

Items	Views held by most of my colleagues					My personal view				
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree
E. Teaching and Learning Science										
1. Science and Aboriginal knowledge should both be taught in a science classroom.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. The primary responsibility of a science teacher is to empower students to think for themselves, thereby emancipating students from a dependency on experts and other authority.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Please provide reasons for your responses in the space below:

APPENDIX 3

Interview Protocol

INTERVIEW PROTOCOL

Introduction

My name is Bente Huntley. I am Métis from the Muskaday First Nations. Currently, I am employed with SUNTEP (Saskatchewan Urban Native Teacher Education Program) in Prince Albert, Saskatchewan. This research project is not a thesis (although I am a graduate student with the U. of S.). It is funded by the Saskatchewan Education Indian and Métis Research Project. The research is being conducted to find out some of the problems that exist for Aboriginal students and to see how we (Saskatchewan Education) can improve Aboriginal students' education and success. This particular project centres around science education and that is an area of special interest to me.

Everything you say will be recorded. To assist me, I will use a recorder as well as notes so I can make sure I don't miss anything or change anything you have stated. I shall stop the recorder at any time you want to talk off the record. For confidentiality you will be given an alias. Yours will be _____. You and I will be the only ones who know your real identity. When I finish transcribing and editing the interview, you will be given a copy to proof read. You can edit this copy and return it to me with any changes or omissions. I also have two copies of an ethics contract for you to read and sign before we begin. Do you have any questions? All tape recordings will be destroyed once you have approved your transcript.

When I talk about science, I'm referring to Western science. The terms "traditional knowledge", "wisdom", and "common knowledge", mean the Aboriginal common knowledge found within the community where you teach.

Initial Questions

1. How long have you been teaching science?

2. How long have you lived/taught in this community?

3. In order to get as broad a range of views as possible on a questionnaire, we asked people to check off the views they thought their colleagues held about each question. Do you find this difficult?

4. When we revise the instrument, do you have any suggestions for improvement?

Questions on Culture

1. The survey deals with your ideas of culture, What does culture mean to you in this context? (i.e. your community)

2. Elders, hunters, trappers and fishermen in your community have their won knowledge and teachings. How do you use that knowledge?
   Do you think that Western science recognizes this knowledge?

3. Please give examples of how science has positively and/or negatively influenced cultural changes in your community.

4. Has science helped some nations colonize other nations of a different culture?
   Do you think science is viewed as a subculture of Western culture?
   Do you believe Western beliefs, values, and conventions are an implicit aspect of science?

5. Do you think students' beliefs in everyday common knowledge (i.e. legends) inhibits their learning science?
   How do people deal with the contradictions?

6. If Aboriginal students master science, do you think they will likely lose something valuable of their own culture? Could you please elaborate.

Worldview Questions

1. Do you feel once scientific knowledge is acquired it often dominates one' way of thinking?

2. If Western science doesn't alienate people from their traditional beliefs, why are so many Aboriginal students intimated and fearful of science?
   Why don't we have more Aboriginal people in the sciences?
   Where are the Aboriginal science educators?
   Why aren't Aboriginal students entering the field of science?

3. Many students say that learning science is like going into a foreign culture. What do you think?
   How then does/can science cross cultural border?

4. How can educators make cultural border crossing easier, if they do exist?

Teaching Questions

1. Many participants agreed that Western science and traditional knowledge should both be taught in schools. Is this happening in your school?
   What are the implications for teaching science in your classroom?
   What would you do, or what do you do, in your own classroom?

2. Many respondents felt the primary responsibility of a science teacher is to empower students to think for themselves; but, they also felt that does not necessarily mean they should be emancipated from a dependency on experts and authority. Could you explain what you think the primary responsibility of a science teacher is, and why do you fee that way?

3. Tell me some of your stories/experiences teaching science in your community.
   Some of the difficulties.
   Some of the success.

Thank you for participating in this research project. As an Aboriginal person, I would like to give you this gift to show you my appreciation. Thank you again for your time and patience. You will receive a copy of the final report. But, I will talk to you again before then.

APPENDIX 4

Ethics Contracts

ETHICS CONTRACT WITH SURVEY PARTICIPANTS

Project Title: Science and Culture Nexus

Please read the following points. They describe the conditions of your participation in the project and how your interests will be safeguarded.

1. Your participation in the project is strictly voluntary.

2. All information collected will be held in strict confidence. You will be anonymous. Only the researchers will have access to your identity. Any records, such as computer files, will refer to you by a number only.

3. Only information relevant to the project will be collected.

4. You own the information we collect from you. If at any time you want your information deleted from the project, we shall do so immediately. You are in control.

5. You will receive an executive summary of the project report in the fall of 1997, and if you wish, we shall send you a copy of the full report.

I have read and understood these points, and I agree to follow them.

Glen Aikenhead — February 28, 1997

Professor Glen Aikenhead — *Date*

University of Saskatchewan
Telephone: (306) 966-7563; FAX (306) 966-7658

Bente Huntley — Feb 28/97

Ms. Bente Huntley — *Date*

Graduate Student, University of Saskatchewan
Telephone: (306) 764-1797; FAX (306) 764-3995

Teacher Participant *(signature)* — *(printed name)*

Date

Participant Indentity # ____

ETHICS CONTRACT WITH INTERVIEW PARTICIPANTS

Project Title: Science and Culture Nexus

Please read the following points. They describe the conditions of your participation in the project and how your interests will be safeguarded.

1. Your participation in the project is strictly voluntary.

2. All information collected will be held in strict confidence. You will be anonymous. Only the researchers will have access to your identity. Any records or files will refer to you by a fictitious name.

3. Only information relevant to the project will be collected.

4. You own the information we collect from you. If at any time you want your information deleted from the project, we shall do so immediately by deleting all tape recordings and destroying all notes, transcriptions, etc. You are in control.

5. You will be asked to read the description/analysis of your interview and to make any changes to ensure your anonymity and accuracy. You control those changes.

6. At the end of the project, all tape recordings involving you will be erased and all interview notes will be destroyed. Only the description/analysis of your interview (see point 5 above) will be a permanent record of the project.

7. You will receive an executive summary of the project report in the fall of 1997, and if you wish, we shall send you a copy of the full report.

I have read and understood these points, and I agree to follow them.

_____ _____

Professor Glen Aikenhead *Date*
University of Saskatchewan
Telephone: (306) 966-7563; FAX (306) 966-7658

_____ _____

Ms. Bente Huntley *Date*
Graduate Student, University of Saskatchewan
Telephone: (306) 764-1797: FAX (306) 764-3995

_____ _____

Teacher Participant (*signature*) (*printed name*)

_____

Date

APPENDIX 5

Revised Version of the SCN Instrument

Science and Culture Nexus Survey[1]

(Saskatchewan Version -- Quant.)

Revised September 23, 1997

Dear Colleague,

This is a survey designed to gather some information on people's perceptions about the nexus (connections) between science and culture. The aim is to document the current views of science educators about culture and Western science, their interactions, and possible effects on student learning and your professional practice. Of specific interest is the connection between First Nations and Métis cultures and the culture of Western science found in the science curriculum. You are invited to be part of this project by completing this questionnaire made up of two sections. Section A seeks biographical information while Section B (five groups of questions) contains the items related to the main focus of the survey.

To complete Section B of the questionnaire please tick √ the box that best represents your personal view. Please do not write your name on the questionnaire. Your responses are confidential and anonymous, and therefore they form part of the aggregated results on all opinions gathered.

Thank you very much.

Sincerely,

Glen Aikenhead
Curriculum Studies
28 Campus Drive
Saskatoon, SK
S7N 0X1
(306) 966-7563

and

Bente Huntley
SUNTEP Prince Albert
48 - 12th Street East
Prince Albert, SK
S6V 1B2
(306) 764-1797

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[1]Derived from an international version composed by O.Jegede, G. Aikenhead, P.A.O. Okebukola, and W. Cobern.

SECTION A:

Biographical Data

1 **Gender:** ☐ Male ☐ Female

2 **Nation/Tribal Aboriginal background:** _____. Fill in either

3 **Ethnic/racial non-Aboriginal background:**_____, 2 or 3, not both

4 **Nationality:**_____

5 **Country of birth:**_____

6 **How long have you lived in your community?:**

☐ Less than 5 years ☐ 5-10 years ☐ 11-15 years ☐ 16-20 years ☐ More than 20 years

7 **Main language spoken at work:**_____

8 **Main language spoken at home:**_____

9 **Principal occupation:**

☐ Science Teacher ☐ Science Teacher Educator ☐ Science Professor/Lecturer

☐ Curriculum Developer ☐ Policy Maker/Administrator ☐ Other (Please specify)_____

10 **Years of experience in your current occupation:**

☐ Less than 5 years ☐ 5-10 years ☐ 11-15 years ☐ 16-20 years ☐ More than 20 years

11 **Highest educational qualification:**

☐ High School/Secondary Certificate ☐ Diploma ☐ Bachelor degree ☐ Masters in _____

☐ Ph.D. in _____ ☐ Other (Please specify)_____

12 **Subject areas of major educational preparation: (check more than 1 if applicable):**

☐ Mathematics ☐ Chemistry ☐ Physics

☐ Biology ☐ Integrated/General Science ☐ Technology/Engineering

☐ Geography ☐ Other (Please specify) _____

13 **Which level of science does your work mostly involve?:**

☐ Primary School (grades 1-6) ☐ Secondary ☐ Primary & Secondary ☐ Teacher Education

☐ University/College Science ☐ Technical Institution ☐ Industry ☐ Other (Please specify) _____

14 **Please identify the cultural identity of the everyday common (indigenous) knowledge in your community:**

_____

15 **Please list areas of major teaching duties:**

_____

SECTION B: SASKATCHEWAN VERSION (revised September 23, 1997)

Instructions: This section seeks your comments on the views held by most of your colleagues you work with or interact with at work or through professional development. Please tick the box which best represents what your personal view is. You may wish to regard 'everyday common knowledge' as 'Aboriginal, indigenous knowledge' in this questionnaire, or whatever you answered in question 14, Section A.

Items	My personal view				
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree
A. Science					
1. Science is best described as:					
a. a body of verified knowledge, such as principles, laws, and theories, which describe and explain the world around us.	☐	☐	☐	☐	☐
b. Exploring the unknown and discovering new things about our world and universe and how they work.	☐	☐	☐	☐	☐
c. Rational perceiving of reality.	☐	☐	☐	☐	☐
d. Inventing or designing things (for example, artificial hearts, computers, space vehicles).	☐	☐	☐	☐	☐
e. Finding and using knowledge to make this world a better place to live in (for example, curing diseases, solving pollution, and improving agriculture).	☐	☐	☐	☐	☐
f. An organization of people (called scientists) who have ideas and techniques for discovering new knowledge.	☐	☐	☐	☐	☐
2. Science is the basis of most technological advances.	☐	☐	☐	☐	☐
3. Technology does not need to have a scientific basis, technology can advance on its own know-how.	☐	☐	☐	☐	☐
4. Science generally represents a male perspective on the world.	☐	☐	☐	☐	☐
5. Every occurrence in nature has a scientific explanation.	☐	☐	☐	☐	☐
6. Science provides the most plausible explanations of natural phenomena.	☐	☐	☐	☐	☐
7. Science can teach how to survive in everyday life situations.	☐	☐	☐	☐	☐

Items	My personal view				
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree
B. Science and Culture					
1. Science is often seen as a subculture of Western culture.	☐	☐	☐	☐	☐
2. Scientific knowledge once acquired often dominates one's way of thinking.	☐	☐	☐	☐	☐
3. Science alienates people from their traditional culture.	☐	☐	☐	☐	☐
4. A person can integrate science with Aboriginal spirituality.	☐	☐	☐	☐	☐
5. If Aboriginal students master science, they will likely lose something valuable of their own culture.	☐	☐	☐	☐	☐
6. Every occurrence in nature has a non-scientific, culture-based explanation.	☐	☐	☐	☐	☐
7. When science is practised in a community, it reflects a community's values and beliefs.	☐	☐	☐	☐	☐
8. Science will progress the same way irrespective of the culture of the scientists involved because science is universal.	☐	☐	☐	☐	☐
9. Science can help the progress of non-Western people if they would only assimilate science into their way of thinking.	☐	☐	☐	☐	☐
10. Science can empower people who belong to a traditional culture, as long as those people learn science without taking on the Western beliefs that are a part of science.	☐	☐	☐	☐	☐
11. Science has helped European nations colonize First Nations peoples.	☐	☐	☐	☐	☐
12. Western beliefs, values, and conventions are an implicit aspect of science.	☐	☐	☐	☐	☐
13. Science teachers attempt to socialize or enculturate students into a community of scientific practitioners.	☐	☐	☐	☐	☐

Items	My personal view				
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree
C. Science and Everyday Common (Indigenous) Knowledge					
1. Scientific ideas are compatible with ideas within an Aboriginal community.	☐	☐	☐	☐	☐
2. Scientific knowledge stands out as being separate from the common knowledge of my community.	☐	☐	☐	☐	☐
3. Science and everyday occurrences are so different, it is almost like they belong to different worlds.	☐	☐	☐	☐	☐
4. Students' belief in everyday common knowledge inhibits their learning science.	☐	☐	☐	☐	☐
5. Evidence arrived at through scientific means is not always regarded as sensible to everyday common knowledge.	☐	☐	☐	☐	☐
6. Scientific explanations and everyday common knowledge of natural phenomena should always be treated as one.	☐	☐	☐	☐	☐
7. It is easy to incorporate science into one's personal views of nature.	☐	☐	☐	☐	☐

Items	My personal view				
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree
D. Culture					
1. Culture is the lifestyle of a people.	☐	☐	☐	☐	☐
2. Culture is a system of meaning that a people create for themselves.	☐	☐	☐	☐	☐
3. Culture is the totality of a people's identity.	☐	☐	☐	☐	☐
4. The expression of culture is influenced most by peers and family members.	☐	☐	☐	☐	☐
5. The culture of a people is permanent because it is transmitted from one generation to another.	☐	☐	☐	☐	☐
6. Cultural knowledge is embodied most of all in one's language.	☐	☐	☐	☐	☐
7. Learning another culture's way of thinking about natural phenomena can empower people by providing them with a new way of thinking.	☐	☐	☐	☐	☐
8. Cultural assimilation can oppress people by marginalizing or dominating their ideas.	☐	☐	☐	☐	☐

Items	My personal view				
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree
E. Teaching and Learning Science					
My responses to items 1 - 14 below will relate to science education at the:					
□ primary level grades 1-6 □ secondary level grades 7-12 □ tertiary level					
1. The teaching of science centres mainly upon the transmission of verified knowledge.	□	□	□	□	□
2. The teaching of science centres mainly upon students making personal meaning out of scientific knowledge.	□	□	□	□	□
3. Most of the current science teaching methods encourage mere acquisition of unrelated information.	□	□	□	□	□
4. The science concepts taught in school science have no meaningful use beyond passing examinations.	□	□	□	□	□
5. Science concepts taught in school reflect the dominant culture in my immediate community.	□	□	□	□	□
6. Science teaches the rejection of ideas held by an Aboriginal community.	□	□	□	□	□
7. School science imposes a foreign set of cultural values on an Aboriginal student.	□	□	□	□	□
8. Science and Aboriginal knowledge can both be taught in a science classroom.	□	□	□	□	□
9. Science and Aboriginal knowledge should both be taught in a science classroom.	□	□	□	□	□
10. For many students, learning science is like going into a foreign culture.	□	□	□	□	□
11. The primary responsibility of a science teacher is to prepare students for post secondary studies.	□	□	□	□	□
12. The primary responsibility of a science teacher is to empower students to think for themselves.	□	□	□	□	□
13. The primary responsibility of a science teacher is to respond to the particular legitimate needs of students, whatever those needs are.	□	□	□	□	□

APPENDIX 6

Tables P1 to P5

Table P1. Number of Participants in Terms of Their Educational Jurisdiction.

Educational Jurisdiction	# interviewees	# contacted by phone for survey	# quant. responses	# qual. responses
Northern Lights School Division	2	21	7	3
Lac La Ronge Indian Band	4	19	7	2
Prince Albert and area	2	10	6	1
Other P.A. Grand Council Schools	1	4	0	1
Saskatoon Board of Education	0	3	3	0
Yorkton Tribal Council	1	2	2	0
Total	***10***	***59***	***25***	***7***

Table P2. SCN Biographical Data of Quantitative Respondents

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1 Gender: **15** Male **10** Female

2 Nation/Tribal Aboriginal background: **3**, Fill in either

3 Ethnic/racial non-Aboriginal background: **22**, 2 or 3, not both

4 Nationality: **Canadian - 24; European - 1**

5 Country of birth: **Canada - 23; Europe - 2**

6 How long have you lived in your community?:

10 Less than 5 years **4** 5-10 years **2** 11-15 years **5** 16-20 years **4** More than 20 years

7 Main language spoken at work: **English - 25**

8 Main language spoken at home: **English - 25**

9 Principal occupation:

15 Science Teacher **0** Science Teacher Educator **0** Science Professor/Lecturer

0 Curriculum Developer **2** Policy Maker/Administrator **8** Other (Please specify)_____

10 Years of experience in your current occupation:

6 Less than 5 years **4** 5-10 years **5** 11-15 years **4** 16-20 years **6** More than 20 years

11 Highest educational qualification:

0 High School/Secondary Certificate **0** Diploma **23** Bachelor degree **2** Masters

2 Ph.D. in Educ. and Chem. **0** Other

12 Subject areas of major educational preparation: (check more than 1 if applicable):

8 Mathematics **5** Chemistry **1** Physics

8 Biology **6** Integrated/General Science **2** Technology/Engineering

2 Geography **11** Other **41 Total**

13 Which level of science does your work mostly involve?:

1 Primary School (grades 1-6) **19** Secondary **5** Primary & Secondary **0** Teacher Education

0 University/College Science **0** Technical Institution **0** Industry **0** Other

14 Please identify the cultural identity of the everyday common (indigenous) knowledge in your community:

First Nations 5, Métis 1, Mixed 11, Urban 6, Other 2

15 Please list areas of major teaching duties:

Varied

Table P3. Biographical Data of Qualitative Respondents

All respondents were born in Canada and are Canadian.

Respondent ID Number	Summary of Biographical Data
10	Female. Continental European background. Less than 5 years in a community of Cree. Cree spoken at school, English at home. Broad range of upper elementary teaching duties.
15	Male. Anglo-European background. 11-15 years in a community of Woodland Cree. English spoken at school and home. Broad range of high school teaching duties.
21	Male. European background. Less than 5 years in a culturally diverse community. English spoken at school and home. Broad range of grade 8 teaching duties.
27	Female. Anglo-European background. 11-15 years in a culturally diverse Northern Saskatchewan community. English spoken at school and home. High school science teaching duties.
39	Female. Continental European background. Less than 5 years in a Cree community. English spoken at school and home. Grades 8-11 science teaching duties.
60	Female. Aboriginal background. 16-20 years in a community largely Cree. English spoken at school and home. Broad range of grade 7 teaching duties.
116	Male. Continental European. Less than 5 years in a Cree community. English spoken at school and home. Broad range of high school subjects.

Table P4. Biographical Data of Interviewees.

Jack is a male non-Aboriginal teacher who has taught grades 10-12 science in a band controlled school for two years. Jack has lived and worked in the community less than five years but has more than twenty years teaching experience. Jack's field of expertise is not science and he has only spent five years throughout his career teaching in the area of science. The main language spoken at home and at work is English.

Larry is a male non-Aboriginal teacher who has taught grades 7-9 science in a northern community for the last five years. The main language spoken at home and at work is English. The school, however, has a high percentage of Aboriginal students: Dene, Cree, Métis, European ancestry. Larry teaches all subject areas but science is one of his areas of expertise.

Betty is a female Aboriginal teacher who has taught grades 7-9 science in an urban school for the last two years. The school has a high percentage of Aboriginal students. The main language spoken at work and home is English. Betty has lived in the community for eighteen years.

Alice is a female Aboriginal teacher who has taught grades 7-9 science for a band controlled school in the south for five years and in the north for one year. Alice has been teaching science for a total of six years. The main language spoken at home and work is English.

Rose is a female non-Aboriginal teacher who has lived and taught in a remote northern community for the past three years. The school has an extremely high percentage of Aboriginal students. The main language spoken at home is English but at school it is Dene. Rose majored in science at the University and now teaches grades 7-9.

Brent is a male non-Aboriginal teacher who has lived and taught in a band controlled school for the past year. The school is situated near an urban centre. The main language spoken at home and work is English. Brent has lived in the surrounding community for over twenty years.

Doug is a male non-Aboriginal teacher who has lived in an urban city for fifty-five years. He has taught science for thirty years in this community. The main language spoken at home and work is English. The high school where Doug teaches has a small percentage of Aboriginal students. Doug teaches grades 10-12 sciences.

Joe is a male Aboriginal teacher who has taught science for fifteen years. He has taught grades 7-9 science in remote northern band schools for the past seven years. The main language spoken at home and work is Cree. As the school principal, Joe spends a half day on administration and a half day teaching. Science is one of the subjects Joe teaches to a multi-graded classroom.

Ted is a male Aboriginal teacher who has lived and taught in a northern band school for the past three years. Ted taught grades 7-9 subjects, including science during his stay in this community. The main language spoken at home and work is English although a large percentage of students speak Cree, their first language, at school.

Gary is a male non-Aboriginal teacher who has lived and taught in a northern community for the past twelve years. He has taught science for twenty-one years and teaches grades 10-12 sciences in a band controlled school. The main language spoken at home and work is English; however, a high percentage of the students do speak Cree at school. Gary holds a Bachelor of Science degree as well as a B.Ed.

Table P5. Subjective Data from the Interviewees

Jack identified himself as "a two-degree person" (line 191 of his transcript) too weak in science to teach it effectively, but he revered those who had a strong science content background. Science was whatever university science professors said it was. A tension existed between science's low status as a frill in his school and science's high status in the eyes of the band chief (lines 92-143).

Larry, a self-confessed story teller (line 158), offered strongly expressed views. He was articulate about the need for students to cross cultural borders between their family culture and school science (lines 110-115), and repeatedly stressed how a strong family culture, whatever culture that was, resulted in success at school (line 67). Although Larry believed that science is what most Western scientists currently believe happens in nature -- a tentative understanding of the world (line 102) -- he was sceptical about scientists' claim to having superior knowledge over other ways of knowing.

Betty described herself as "a sciencing teacher" (line 130) who viewed student learning as making connections as evidenced by "the wheels are clicking" (line 442). Only hands-on activities result in student comprehension (570), which she contrasts with textbook teaching of her colleagues. Science is knowledge that all cultures have in their own way, so Western science is the knowledge of Western culture (line 109).

Alice, too, emphasized activity-oriented learning. However, she would not speak about Aboriginal students in general (line 154), because everything varied according to the individual student (line 179). Alice offered articulate *descriptions* but remained largely silent on topics requiring her *inferences*. Science is alive; science is not a static body of knowledge (line 313).

Rose, a science major in her B.Ed. elementary program, stressed that learning is making connections to one's life (line 209), and that success follows from self-confidence in one's abilities (line 188). A theme in her interview was the need to encourage students into science-related fields. She seemed to accept Western science as the definitive knowledge system for explaining nature. She did not compare it with First Nations knowledge of nature.

Brent, a first year teacher, expressed frustration over students who thought they could not learn when they actually could. Although an enthusiastic physics teacher, Brent felt that physics had its limitations. He described science as being preoccupied with obtaining knowledge for the sake of knowledge (line 286). "What's wrong with a little mystery?" (line 288), he asked when talking about science not knowing everything about nature. He was sceptical about the authority that science enjoys in Canadian culture (line 300).

Doug, with 30 years of teaching experience, mentioned retirement. He emphasized his own personal connections to First Nations culture and how he attempted to validate students' culture by adding details to his science lessons, for example, adding Cree names in biology classes (line 310). But grade 12 science is undoubtedly all about preparation for university science (line 435). To Doug, science has verifiable knowledge. Based on this characteristic, he distinguished science from other ways of knowing -- different but equal (line 189). Thus he accepted the authority of science but not the claim that science is better than First Nations knowledge of nature.

Table P5 (continued)

Joe, more than any other Aboriginal interviewee, offered a glimpse into a First Nations orientation to learning: autonomy of the individual, centrality of careful observations, the internalization of knowledge by students, and the need to "learn the hard way" (line 196). He emphasized that students "take things for granted which is a cultural sort of thing" (line 325). Joe seemed to accept Western science as an authoritative knowledge system, but one that did not interfere with his Aboriginal way of knowing (line 128).

Ted, more than any other interviewee, explicitly rejected assimilation (line 412). he also felt that students learn a great deal of knowledge at home (line 120), and that hands-on activities are essential to learning (line 612). Like Joe, Ted seemed to accept the authority of science without it interfering with his Aboriginal way of knowing (line 412).

Gary's 21 years of experience teaching had put him in contact with many traditional cultural resources. He emphasized the goal of autonomous critical thinking (line 369), but on the other hand, he drew uncritically upon left-brain right-brain metaphors (line 498). His view of science was captured in his own words, "Native people themselves use and practise chemistry all the time and understand it" (line 180).

APPENDIX 7

Tables A to E

Table A. SCN Data: Science

Items	My personal view					
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree	Average
	(1)	(2)	(3)	(4)	(5)	
A. Science						
1. Science is a body of verified knowledge, such as principles, laws, and theories, which describe and explain the world around us.	7	13	3	2	0	2.0
2. Science is exploring the unknown and discovering new things about our world and universe and how they work.	11	13	0	1	0	1.6
3. Science is carrying out experiments to solve problems of interest about the world around us.	7	14	1	1	0	1.9
4. Science is inventing or designing things (for example, artificial hearts, computers, space vehicles).	5	11	1	5	1	2.4
5. Science is finding and using knowledge to make this world a better place to live in (for example, curing diseases, solving pollution, and improving agriculture).	7	13	2	1	1	2.0
6. Science is an organization of people (called scientists) who have ideas and techniques for discovering new knowledge.	3	10	2	6	2	2.7
7. Science is a rational perceiving of reality.	3	16	2	3	0	2.2
8. Science is the basis of most technological advances.	6	13	3	3	0	2.1
9. Technology does not need to have a scientific basis, technology can advance on its own know-how.	1	5	4	11	3	3.4
10. Science generally represents a male perspective on the world.	1	6	3	13	2	3.4
11. Every occurrence in nature has a scientific explanation.	1	8	1	11	3	3.3
12. Science represents a wholistic/comprehensive perspective about natural phenomena.	0	9	5	9	1	3.1
13. Science provides the most plausible explanations of natural phenomena.	2	16	2	5	0	2.4

Table B: SCN Data: Science and Culture

	Items	My personal view					
		Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree	Average
		(1)	(2)	(3)	(4)	(5)	
B.	**Science and Culture**						
1.	Science teachers attempt to socialize/or enculturate students into a community of scientific practitioners.	1	14	1	9	0	2.7
2.	It is easy to incorporate science into one's personal views of nature.	2	16	4	3	0	2.3
3.	Scientific knowledge once acquired often dominates one's way of thinking.	3	15	0	7	0	2.4
4.	Science alienates people from their traditional culture.	0	3	3	16	2	3.7
5.	A person can integrate science with Aboriginal spirituality.	0	11	9	2	1	2.7
6.	My community appears to be turning against science.	0	1	5	14	5	3.9
7.	Science is often seen as a subculture of Western culture.	0	10	6	8	1	3.0
8.	Every occurrence in nature has a non-scientific/ culture-based explanation.	1	8	4	10	1	3.1
9.	Many of nature's occurrences are mysterious.	3	16	2	4	0	2.3
10.	Science can teach how to survive in everyday life situations.	1	16	2	6	0	2.5
11.	When science is practised in a community, it reflects a community's values and beliefs.	0	12	6	6	0	2.8
12.	Science will progress the same way irrespective of the culture of the scientists involved because science is universal.	0	7	6	11	1	3.2
13.	Western beliefs, values, and conventions are an implicit aspect of science.	1	10	7	7	0	2.8
14.	Science can help the progress of non-Western people if they would only assimilate science into their way of thinking.	0	8	11	5	1	3.0
15.	Science can empower people who belong to a traditional culture, as long as those people learn science without taking on the Western beliefs that are a part of science.	1	13	5	4	1	2.6
16.	Science has helped some nations colonize other nations of a different culture.	3	12	8	2	0	2.4

Table C: SCN Data: Science and Everyday Common (Indigenous) Knowledge

	Items	My personal view					
		Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree	Average
		(1)	(2)	(3)	(4)	(5)	
C.	**Science and Everyday Common (Indigenous) Knowledge**						
1.	Scientific ideas and everyday common knowledge within my immediate community have similarities.	1	16	4	4		2.4
2.	Scientific knowledge stands out as being separate from the common knowledge of my community.	1	8	5	11		3.0
3.	Science and everyday occurrences are so different, it is almost like they belong to different worlds.	0	2	0	18	5	4.0
4.	Scientists/science educators often use scientific ideas to support ideas found in everyday common knowledge.	3	20	2	0	0	2.0
5.	Scientists/science educators often use ideas from everyday common knowledge to support scientific ideas.	4	20	1	0	0	1.9
6.	Students' belief in everyday common knowledge inhibits their learning science.	1	4	2	13	5	3.7
7.	Evidence arrived at through scientific means is not always regarded as sensible to everyday common knowledge.	1	7	9	8	0	3.0
8.	Scientific explanations and everyday common knowledge of natural phenomena should always be treated differently.	0	1	6	16	2	3.8
9.	Scientific explanations and everyday common knowledge of natural phenomena should always be treated as one.	0	4	6	14	1	3.5
10.	Scientific explanations of natural phenomena are relevant to everyday societal issues.	2	15	6	2	0	2.3

Table D. SCN Data: Culture

	Items	My personal view					
		Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree	Average
		(1)	(2)	(3)	(4)	(5)	
D.	**Culture**						
1.	Culture is the lifestyle of a people.	2	19	2	2	0	2.2
2.	Everything that is not nature is culture.	0	4	4	14	3	3.6
3.	Culture is a system of meaning that a people create for themselves.	1	19	2	3	0	2.3
4.	Culture is the totality of a people's identity.	1	13	1	9	1	2.8
5.	The expression of culture is influenced most by peers and family members.	1	23	1	0	0	2.0
6.	The culture of a people is permanent because it is transmitted from one generation to another.	0	2	3	17	3	3.8
7.	Cultural knowledge is embodied most of all in one's language.	2	9	7	6	1	2.8
8.	Cultural hybrid results from inter-marriages between people of different cultures.	1	14	6	4	0	2.5
9.	Nature (heredity), rather than nurture (environment), influences cultural change.	0	0	3	18	4	4.0
10.	Nurture, rather than nature, influences cultural change.	4	15	3	3	0	2.2
11.	Both nurture and nature interact and influence cultural change.	5	14	2	4	0	2.2
12.	Learning another culture's way of thinking about natural phenomena can empower people by providing them with a new way of thinking.	4	18	1	2	0	2.0
13.	Cultural assimilation can oppress people by marginalizing or dominating their ideas.	4	12	3	4	2	2.5

Table E: SCN Data: Teaching and Learning Science

Items	My personal view					
	Definitely Agree	Agree	Not Sure	Disagree	Definitely Disagree	Average
	(1)	(2)	(3)	(4)	(5)	
E. Teaching and Learning Science						
My responses to items 1 - 14 below will relate to science education at the:						
☐ primary level grades 1-6 ☐ secondary level grades 7-12 ☐ tertiary level	primary: 1 secondary: 24					
1. The teaching of science centres mainly upon the transmission of verified knowledge.	0	12	2	8	2	3.0
2. The teaching of science centres mainly upon students making personal meaning out of scientific knowledge.	2	15	1	7	0	2.5
3. Most of the current science teaching methods encourage mere acquisition of unrelated information.	0	5	3	14	3	3.6
4. Science concepts taught in school reflect the dominant culture in my immediate community.	0	7	5	11	2	3.3
5. Scientific ideas are compatible with ideas within an Aboriginal community.	2	11	8	3	1	2.6
6. Science teaches the rejection of ideas held by an Aboriginal community.	0	1	6	17	0	3.7
7. School science imposes a foreign set of cultural values on an Aboriginal student.	0	5	4	15	1	3.5
8. Science and Aboriginal knowledge can both be taught in a science classroom..	5	17	1	1	0	2.0
9. Science and Aboriginal knowledge should both be taught in a science classroom..	5	10	6	3	1	2.4
10. The science concepts taught in school science have no meaningful use beyond passing examinations.	0	1	0	8	15	4.5
11. The primary responsibility of a science teacher is to prepare students for postsecondary studies.	0	7	1	10	7	3.7
12. The primary responsibility of a science teacher is to empower students to think for themselves, thereby emancipating students from a dependency on experts and other authority.	9	13	2	1	0	1.8
13. The primary responsibility of a science teacher is to respond to the particular legitimate needs of students, whatever those needs are.	1	14	6	4	0	2.5
14. If Aboriginal students master science, they will likely lose something valuable of their own culture.	0	3	2	12	8	4.0
15. For many students, learning science is like going into a foreign culture.	1	11	5	6	2	2.9

APPENDIX 8

Tables B4, B15, E9, E12,
Z1, Z2

Table B4. Responses to: "Science alienates people from their traditional culture."

Teacher	Response
60	Yes, but only if one allow it; for example, if a rigid teacher insists on alienating a student.
27	No, Native students are as interested in all areas of science as any other student.
39	No, scientific 'facts' do not have to replace the science in a traditional culture.
116	No, science should empower people. Alcohol, drugs and the Indian Act alienates people.
21	No, there is no conflict, so there is no alienation.
10	No, it is best to learn as much as possible.
15	No, natural science reinforces traditional Native views.

Table B15. Responses to: "Science can empower people who belong to a traditional culture, as long as those people learn science without taking on the Western beliefs that are a part of science."

Teacher	Response
15	Yes, indigenous peoples always had a good understanding of the basic laws of science.
10	No, not knowing something is ignorance. Therefore, learn as much as possible.
27	No, there is no conflict between Native culture and natural science. Elders know science even though not from a book.
39	No, there are "two ways of knowing," one does not have a negative effect on the other.
60	No, blending and understanding of views broadens one's worldview. Western science is not racist, it is simply the dominant worldview.
21	No, there is no conflict, as evidenced by the cultural diversity of scientists worldwide. One does not need to hold on to Western beliefs to be a scientists.
116	The two belief systems conflict. Certain beliefs must be adopted from the Western society and some traditional ones must be compromised, or the study of science cannot happen.

Table E9. Responses to: "Science and Aboriginal knowledge should both be taught in a science classroom."

Teacher	Response
15	Yes, "indigenous peoples always had a good understanding of the basic laws of science. ... Traditional Native beliefs about the material laws of interacting with the environment must be incorporated into all science teachings."
116	Yes, a balance must exist for both types of thought. "The broader the knowledge, the better equipped the individual students are to exist in both worlds."
39	Yes, but it's difficult. You need a lot of community involvement. You should not teach "students about Aboriginal knowledge from a textbook; it needs to come from their own people."
60	Yes, but the resource people are very scarce. Many teachers don't feel qualified to teach Aboriginal knowledge.
21	Science is science, it crosses cultural borders. Knowing more about different cultures empowers students.
27	Not sure. We only need to teach "(1) a love of learning, and (2) where to look for answers; to have generations of great Aboriginal scientists coming up."

Table E12. Responses to "The primary responsibility of a science teacher is to empower students to think for themselves, thereby emancipating students from a dependency on experts and other authority.

Teacher	Response
116	Yes, instill in students the right and duty to question and defend their own ideas and the ideas of others. This creates responsible thoughtful citizens.
39	Yes, but empowerment doesn't mean one is completely independent.
60	Yes, but there is a need for the 'more knowledgeable' to guide.
10	Yes, students should think for themselves, but not be emancipated from experts such as elders from whom everyone can learn.
21	No, students should think for themselves, but that doesn't mean we let go of experts and authorities.

Table Z1. Consequences to Mastering Science: Quantitative Data

	Item	Number of teachers who agree / disagree	
E14	If Aboriginal students master science, they will likely lose something valuable of their own culture.	3	20
B4	Science alienates people from their traditional culture.	3	18
E6	Science teaches the rejection of ideas held by an Aboriginal community.	1	17
E7	School science imposes a foreign set of cultural values on an Aboriginal student.	5	16
B3	Scientific knowledge once acquired often dominates one's way of thinking.	18	7

Table Z2. Primary Responsibility of Teachers: Quantitative Data

	Item	Number of teachers who agree / disagree	
E12	The primary responsibility of a science teacher is to empower students to think for themselves, thereby emancipating students from a dependency on experts and other authority.	22	1
E13	The primary responsibility of a science teacher is to respond to the particular legitimate needs of students, whatever those needs are.	15	4
E11	The primary responsibility of a science teacher is to prepare students for postsecondary studies.	7	17